

[54] NUCLEAR FUEL HANDLING APPARATUS

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[52] U.S. Cl. **176/30**

[51] Int. Cl.² **G21C 19/20**

[58] Field of Search 176/30, 31, 32, 28; 214/18 H

[56] **References Cited**

UNITED STATES PATENTS

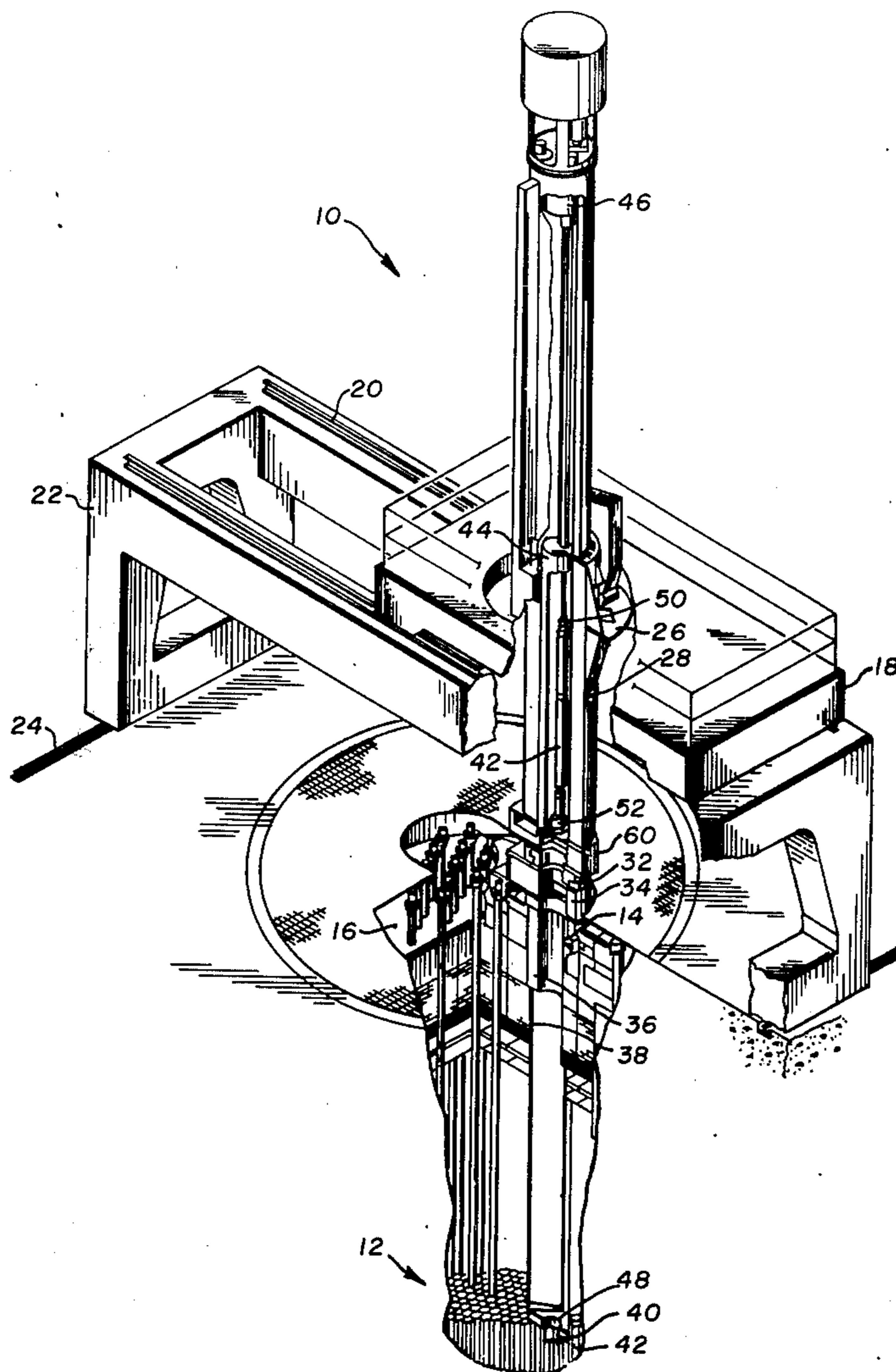
3,629,062 12/1971 Muenchow 176/31

Primary Examiner—Samuel Feinberg
Attorney, Agent, or Firm—Edward L. Kochev, Jr.;
Frederick A. Goettel, Jr.

[57] **ABSTRACT**

A fuel handling machine for a liquid metal cooled nuclear reactor in which a retractable handling tube and gripper are lowered into the reactor to withdraw a spent fuel assembly into the handling tube. The handling tube containing the fuel assembly immersed in liquid sodium is then withdrawn completely from the reactor into the outer barrel of the handling machine. The machine is then used to transport the spent fuel assembly directly to a remotely located decay tank. The fuel handling machine includes a decay heat removal system which continuously removes heat from the interior of the handling tube and which is capable of operating at its full cooling capacity at all times. The handling tube is supported in the machine from an articulated joint which enables it to readily align itself with the correct position in the core. An emergency sodium supply is carried directly by the machine to provide make up in the event of a loss of sodium from the handling tube during transport to the decay tank.

5 Claims, 32 Drawing Figures



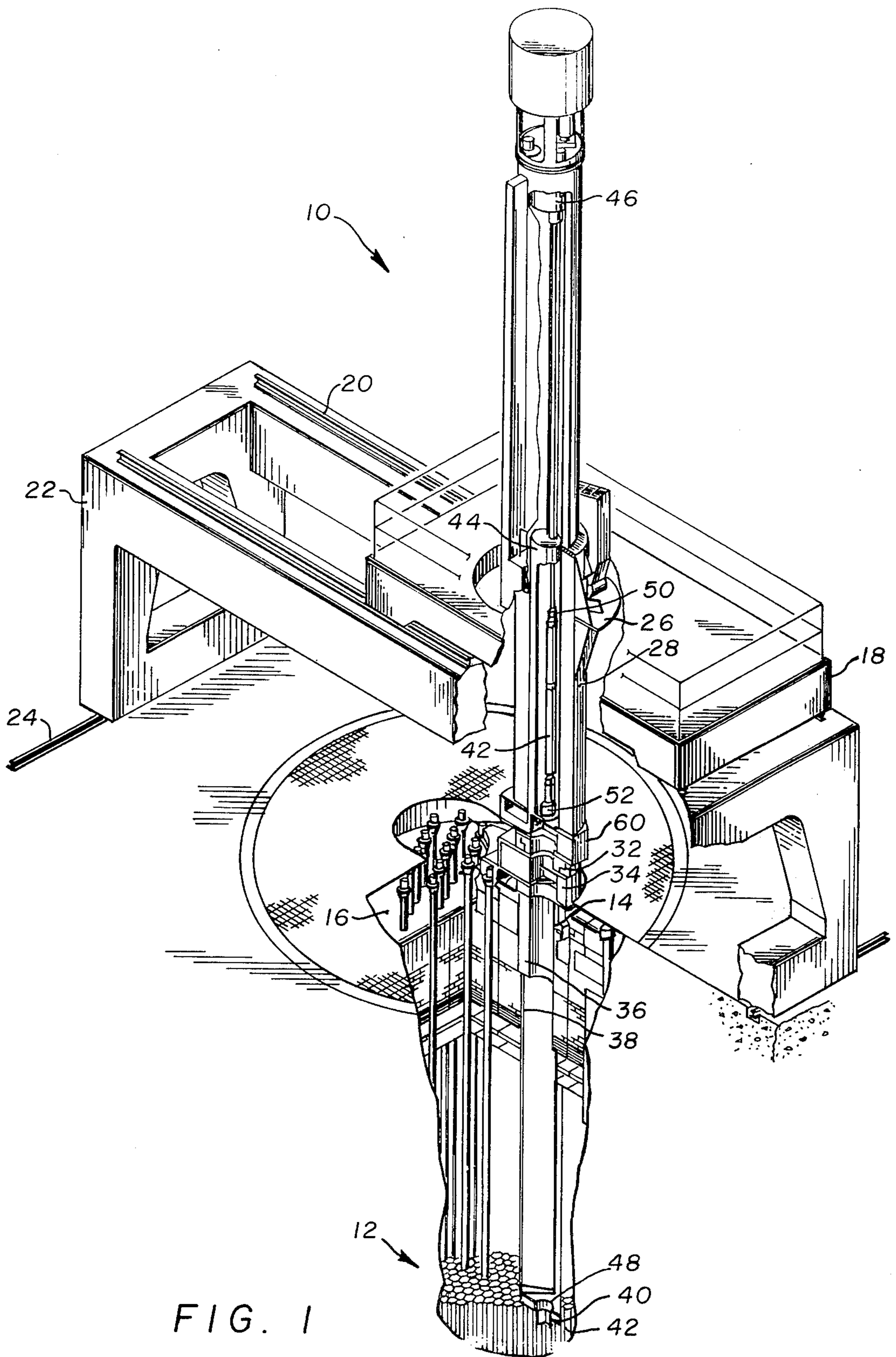


FIG. 1

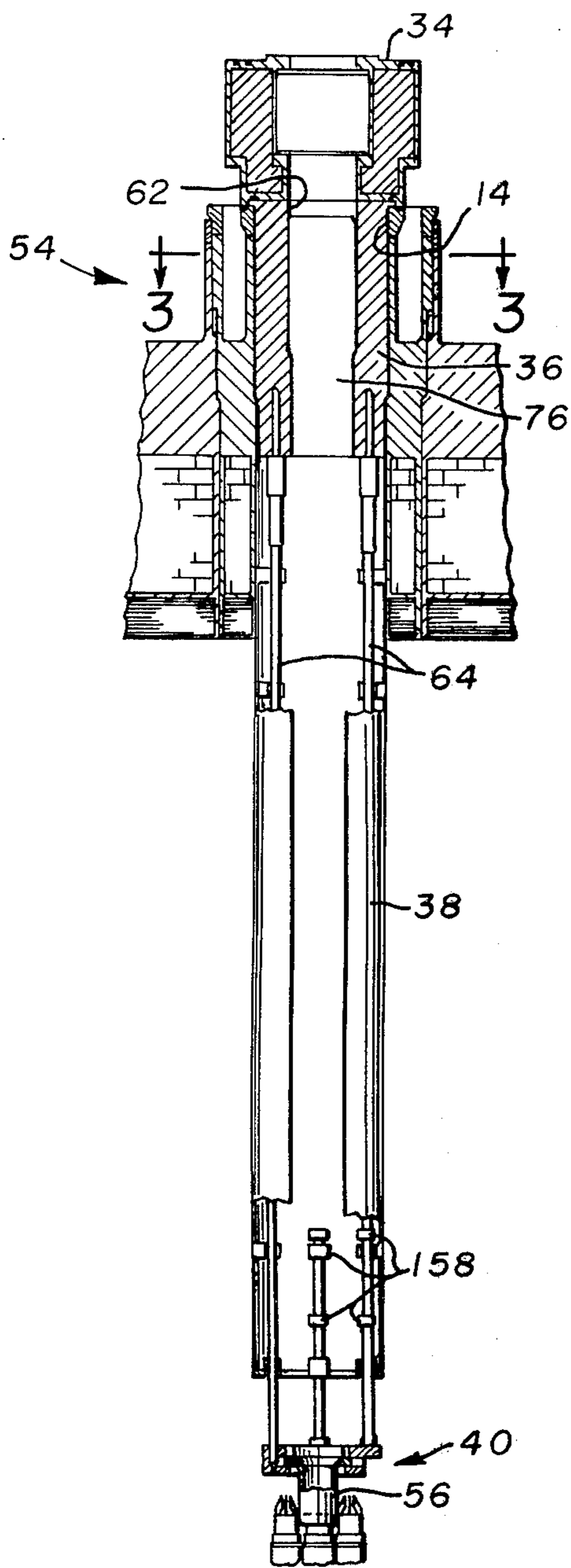


FIG. 2

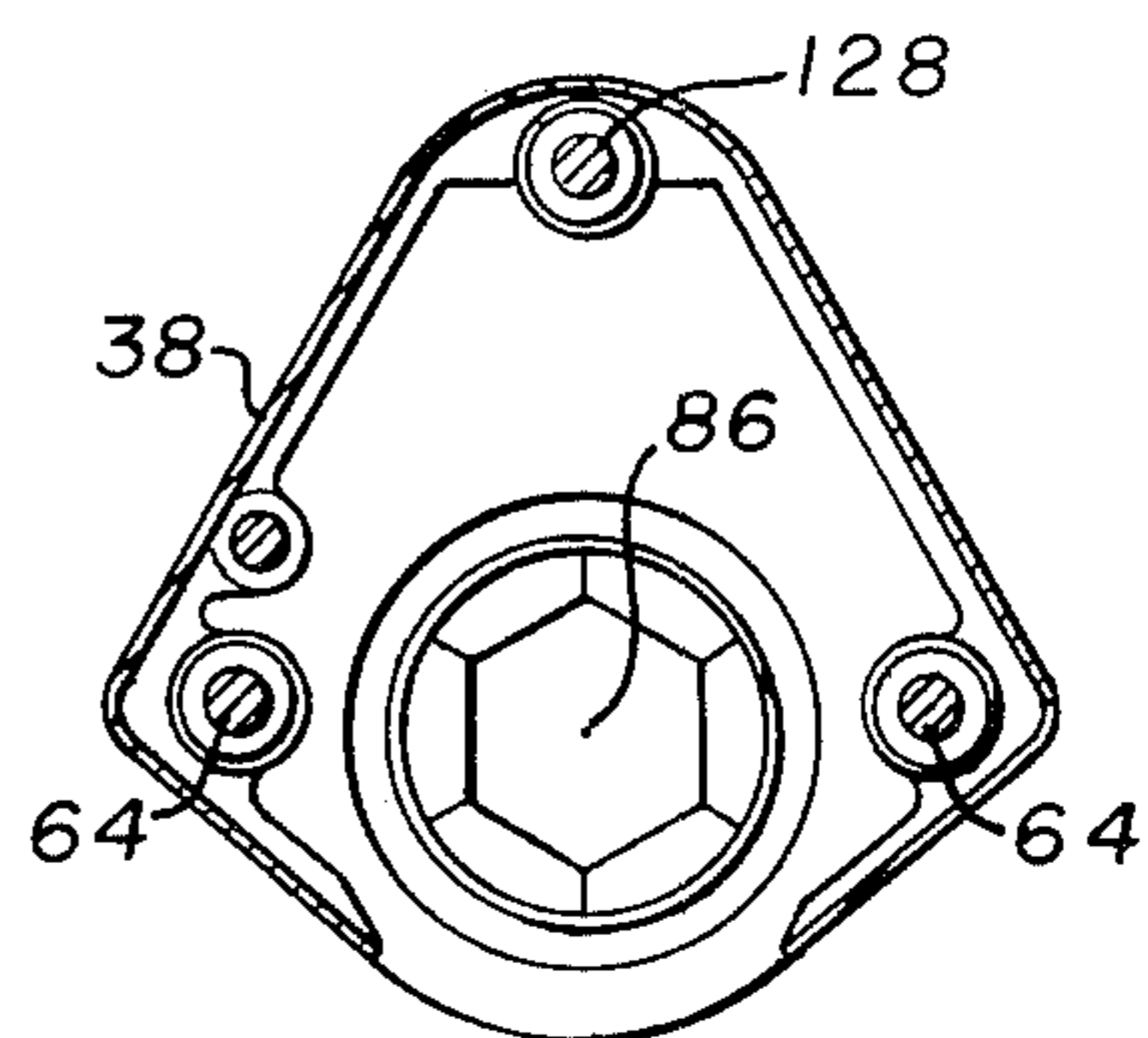


FIG. 7

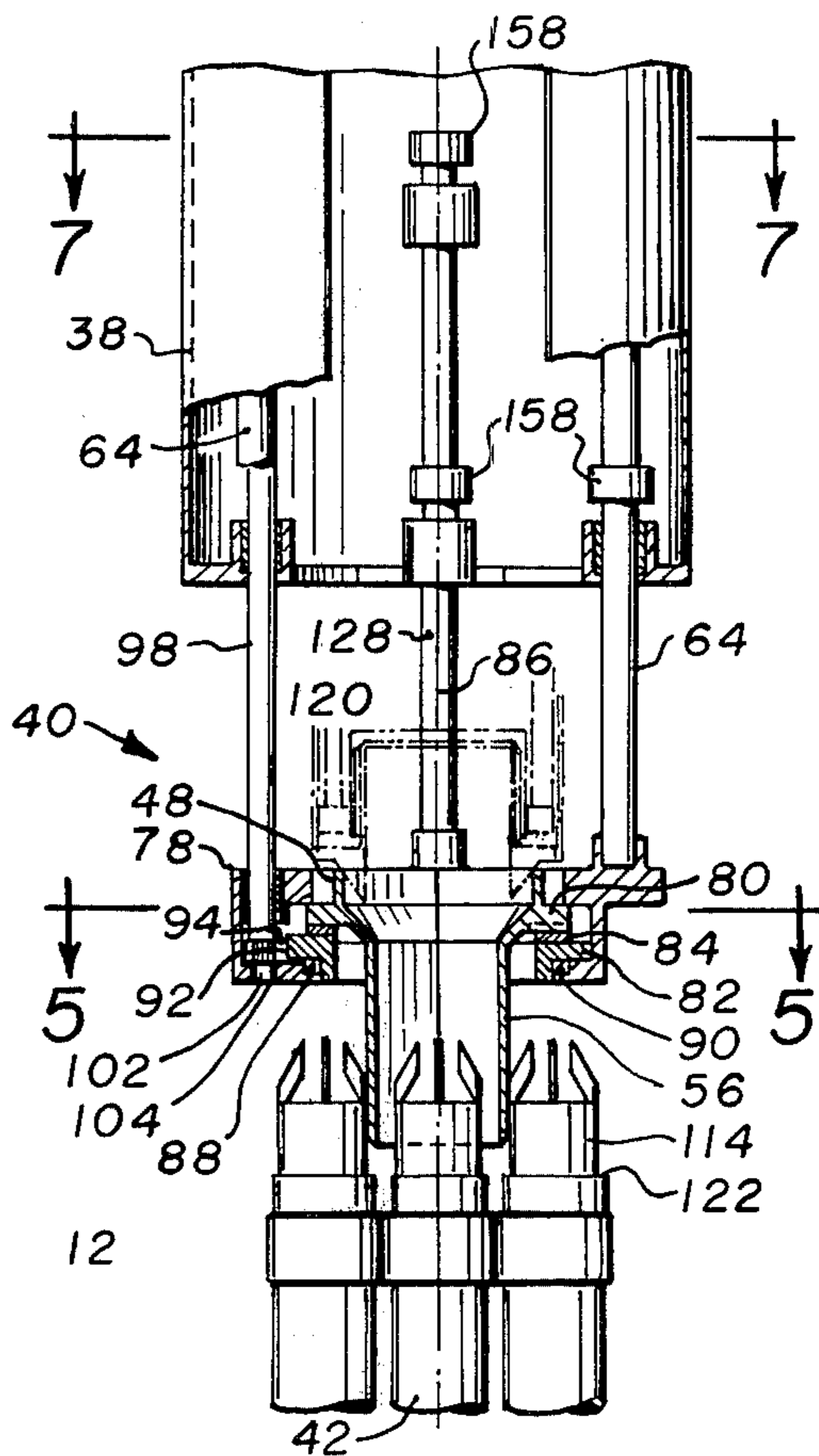


FIG. 4

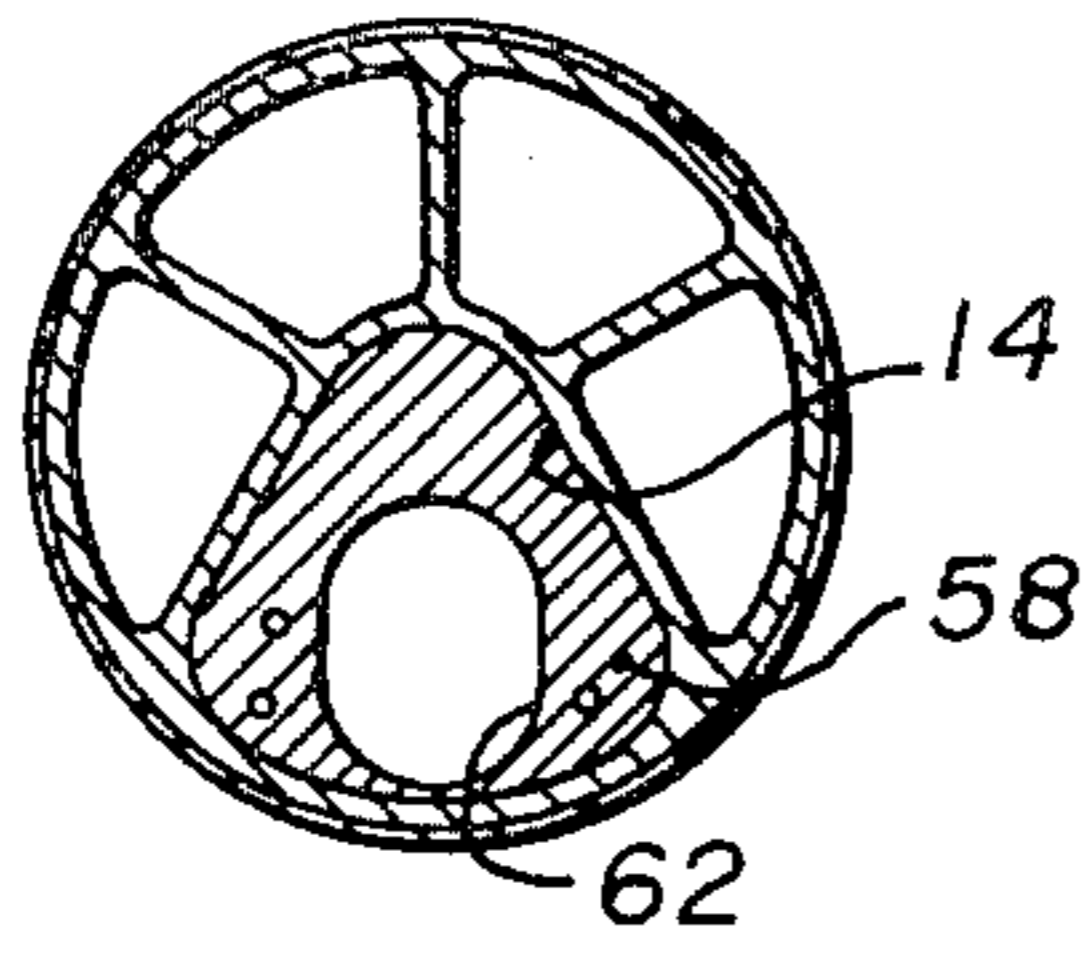


FIG. 3

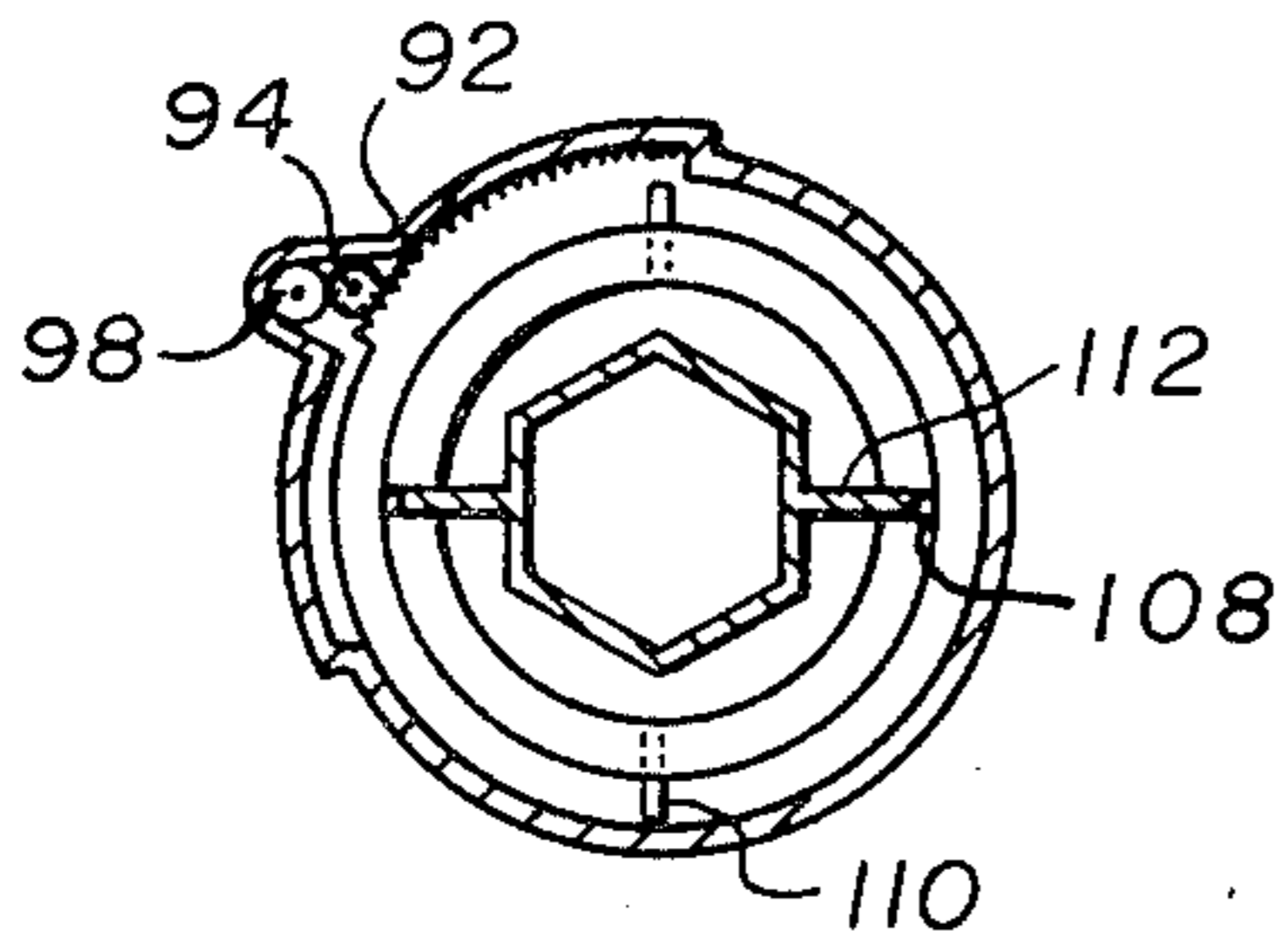


FIG. 5

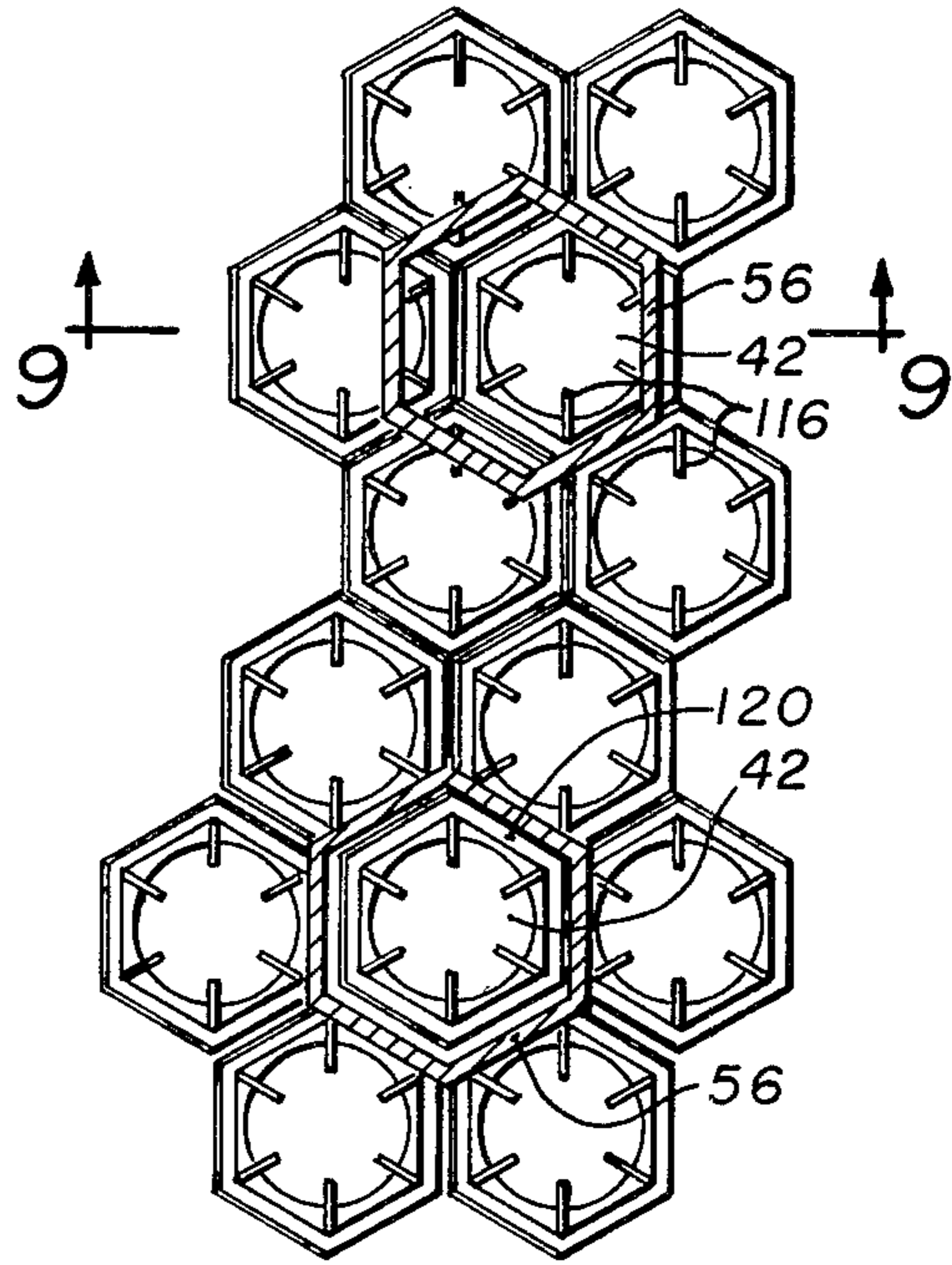


FIG. 8

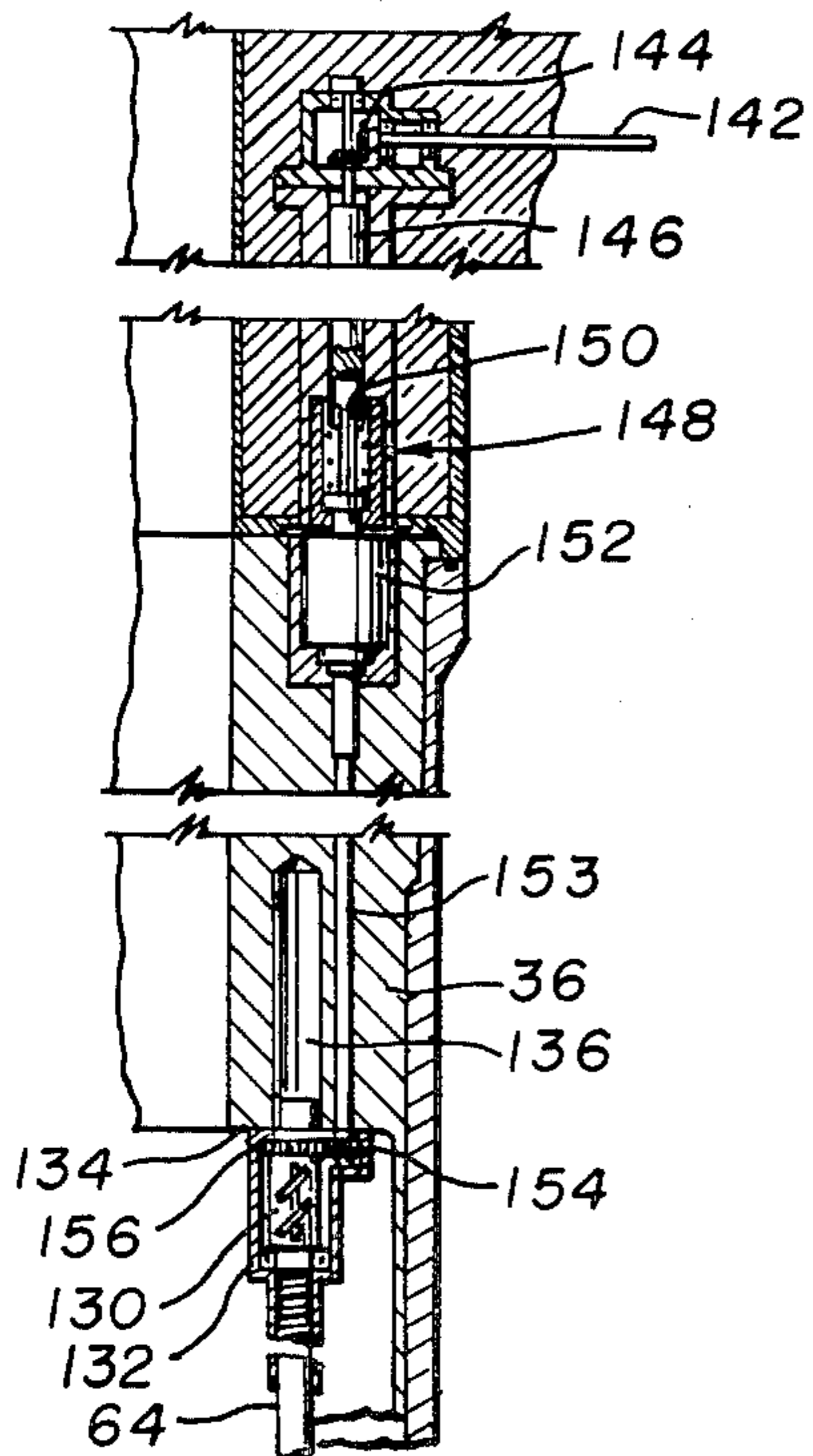


FIG. 12

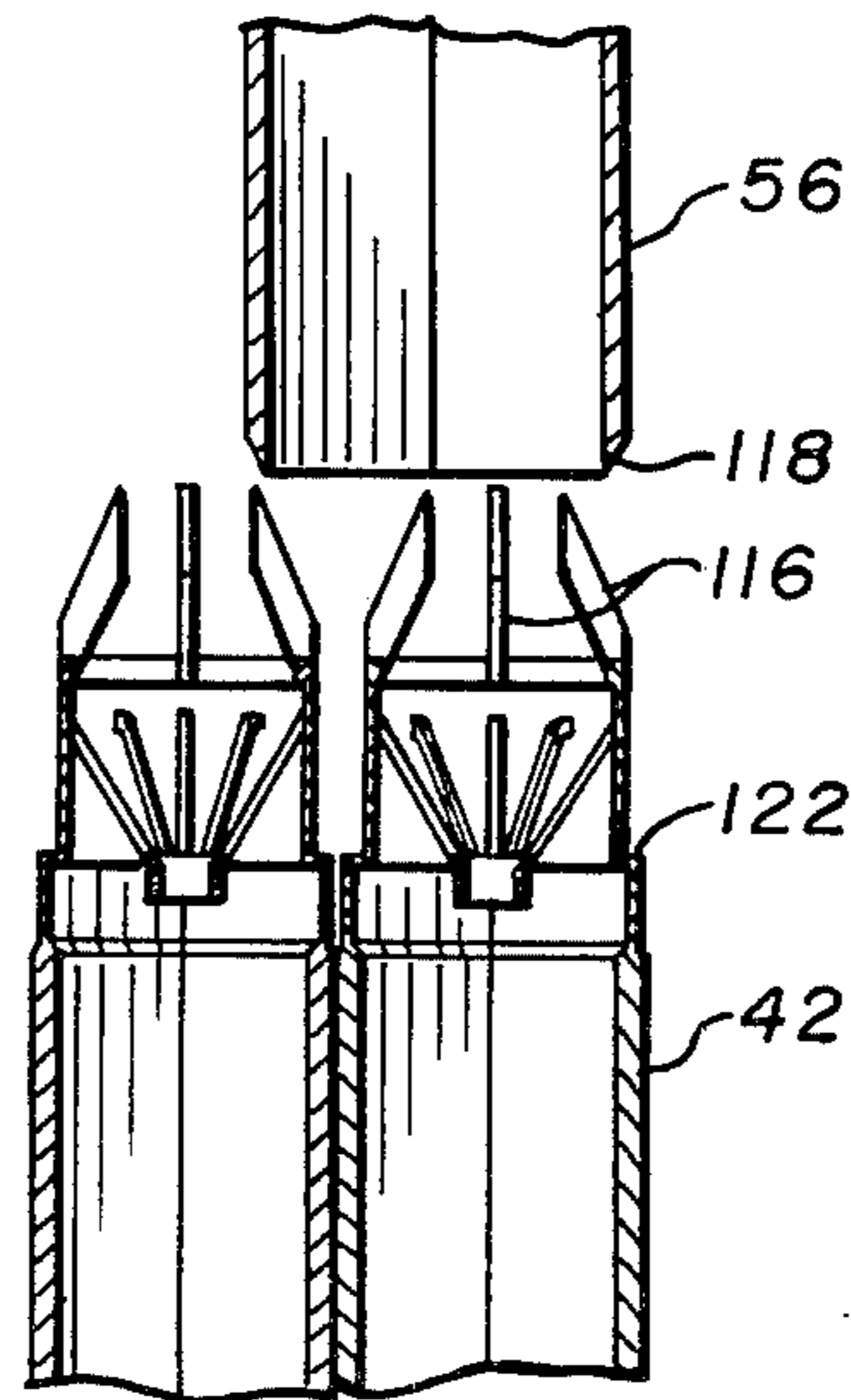


FIG. 9

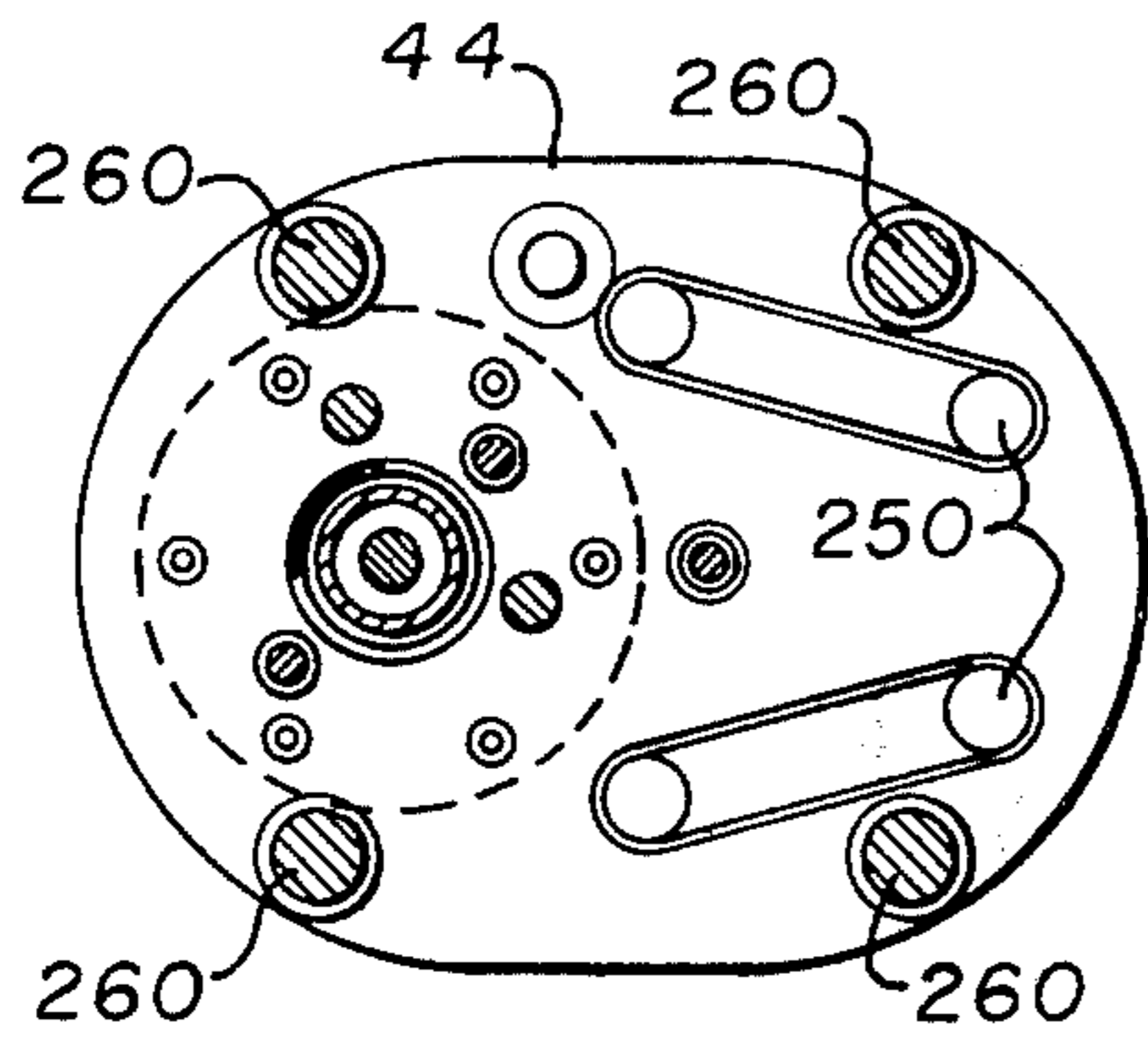


FIG. 17

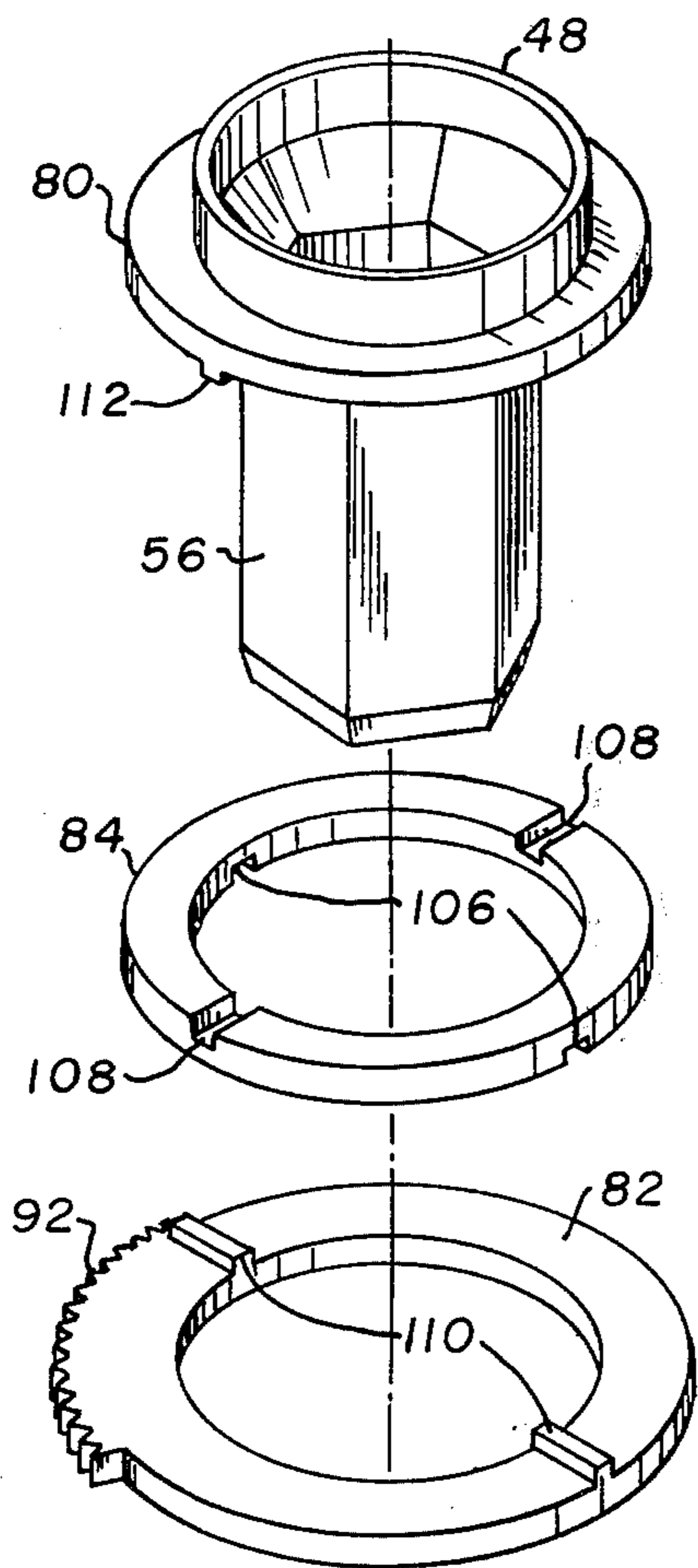


FIG. 6

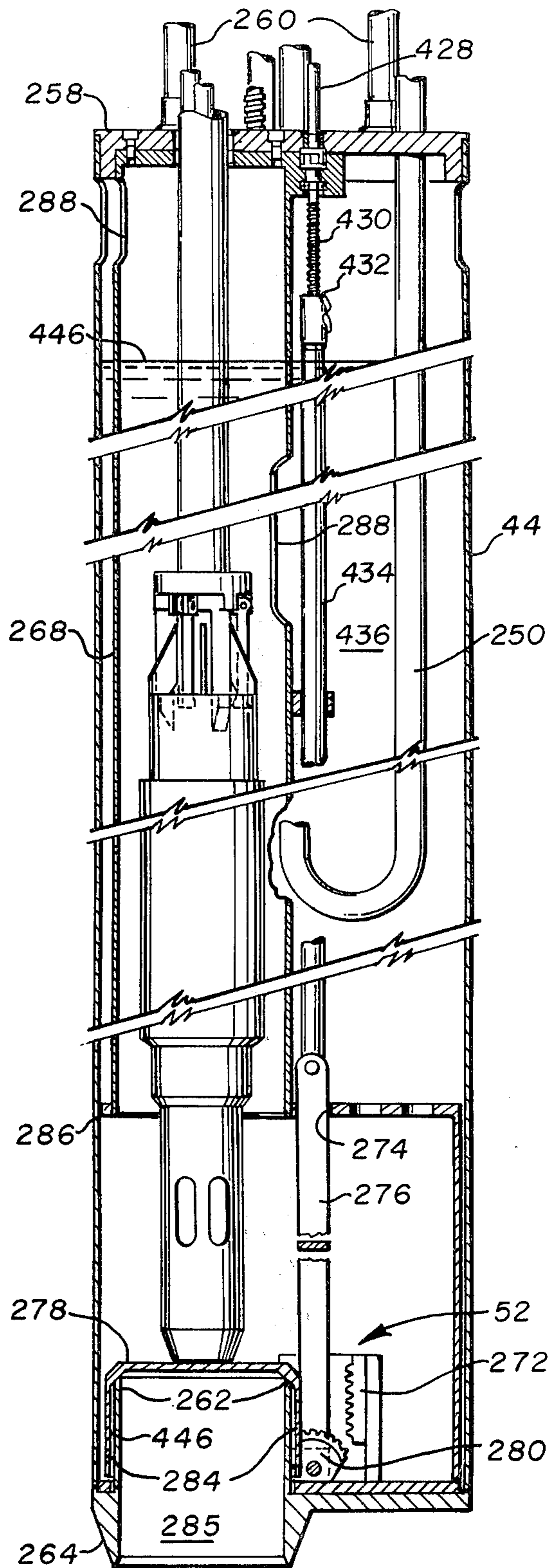


FIG. 16

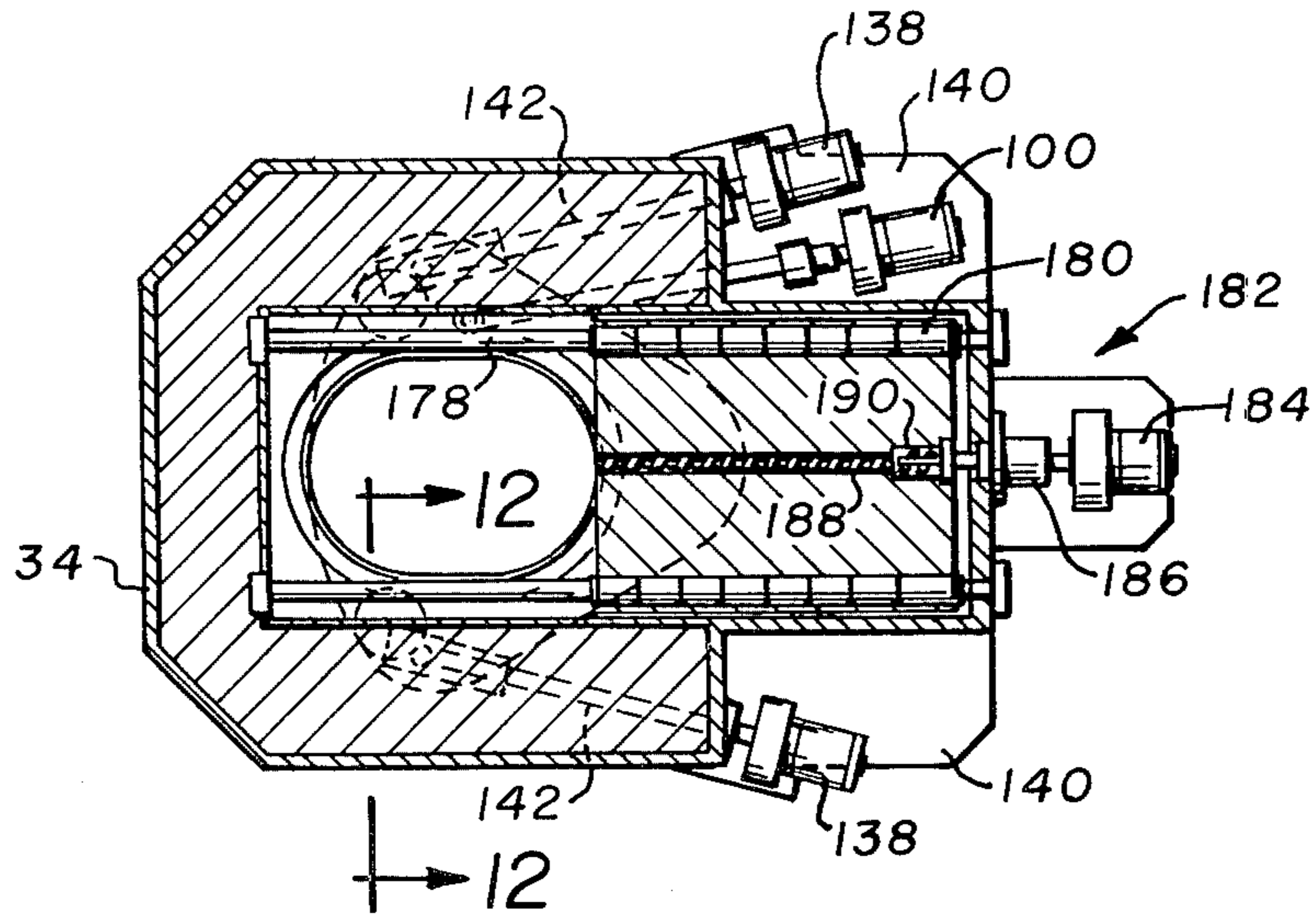


FIG. 11

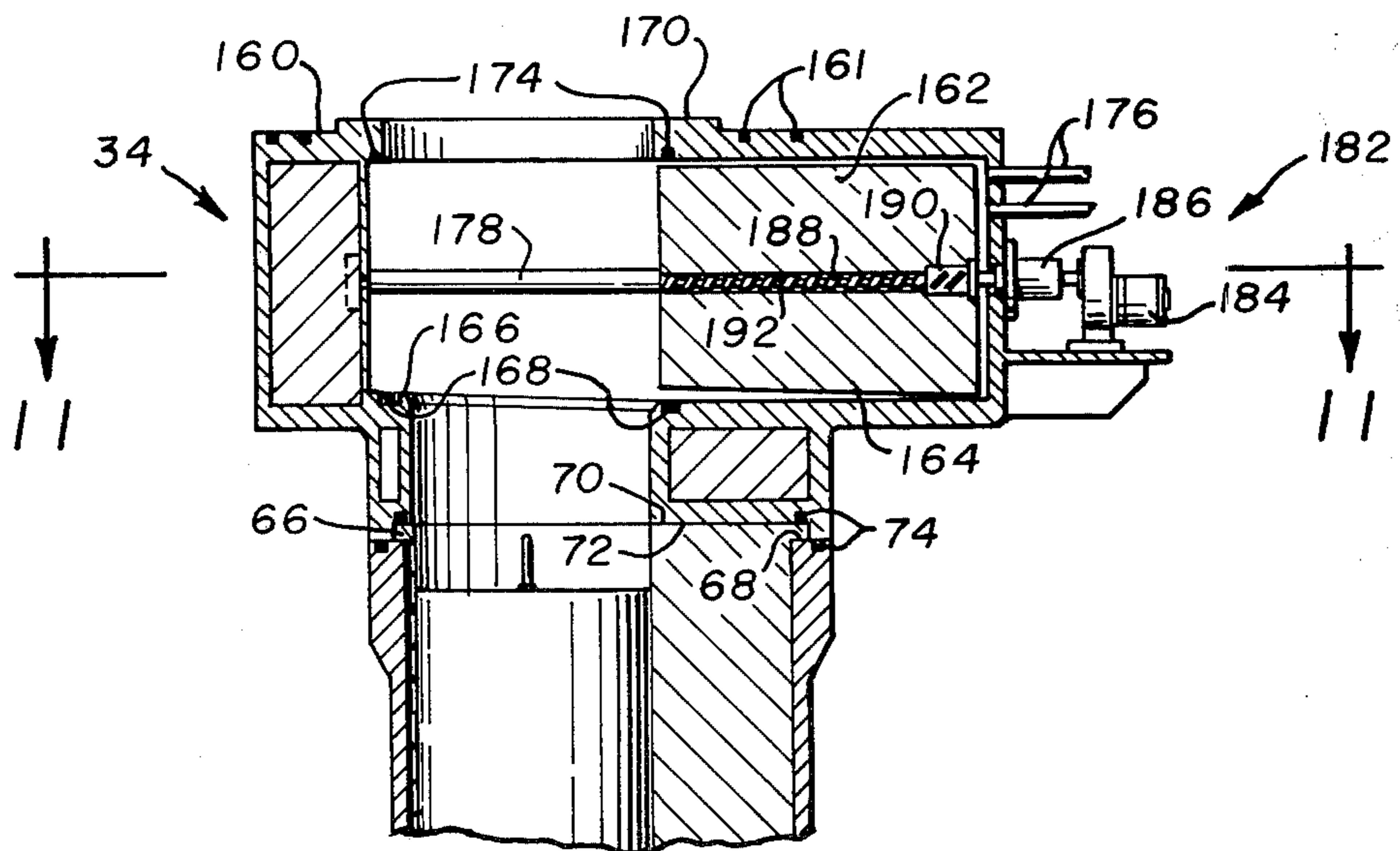


FIG. 10

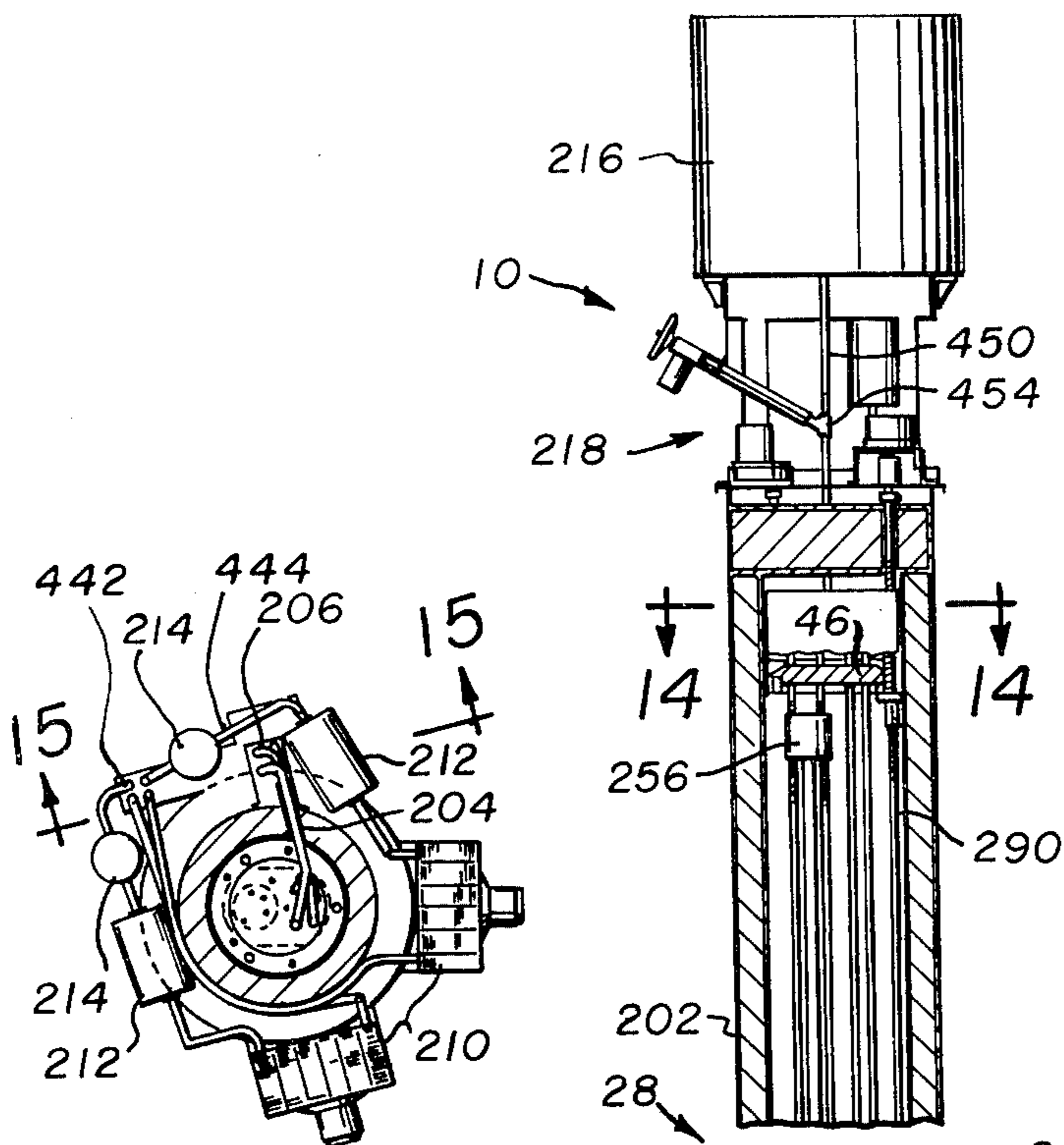


FIG. 14

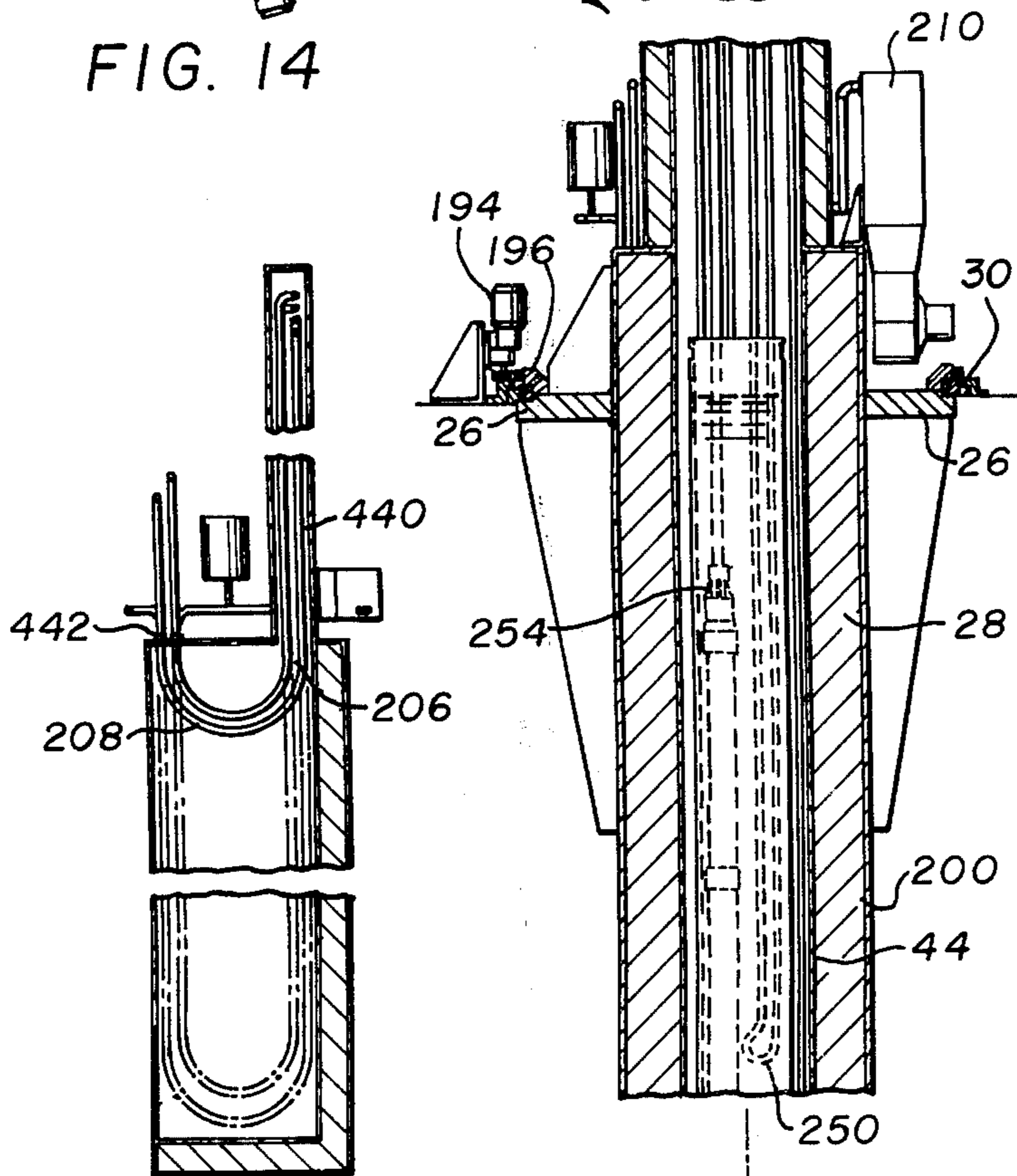


FIG. 15

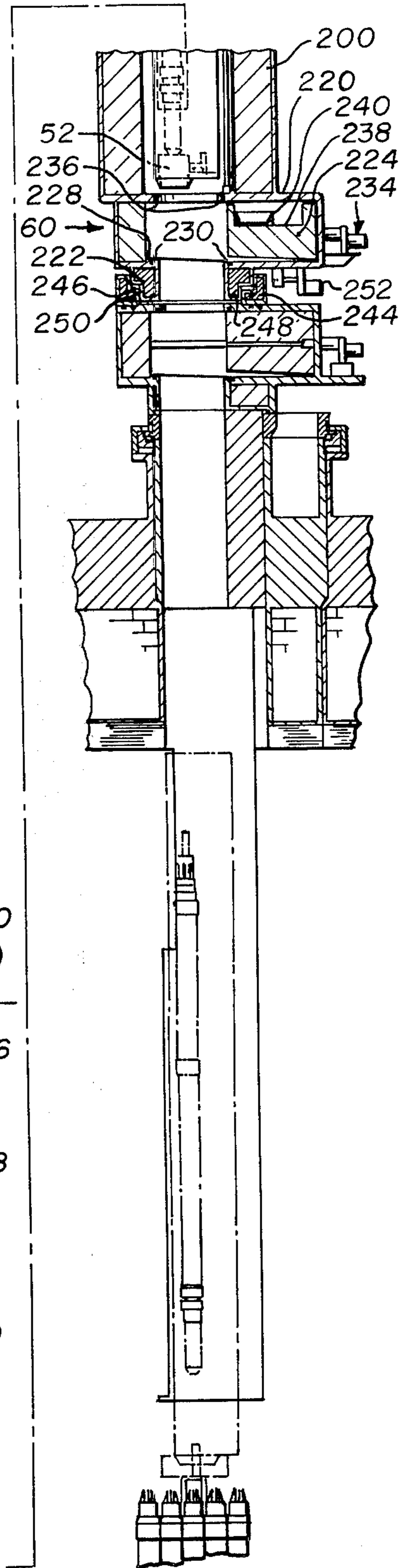


FIG. 13

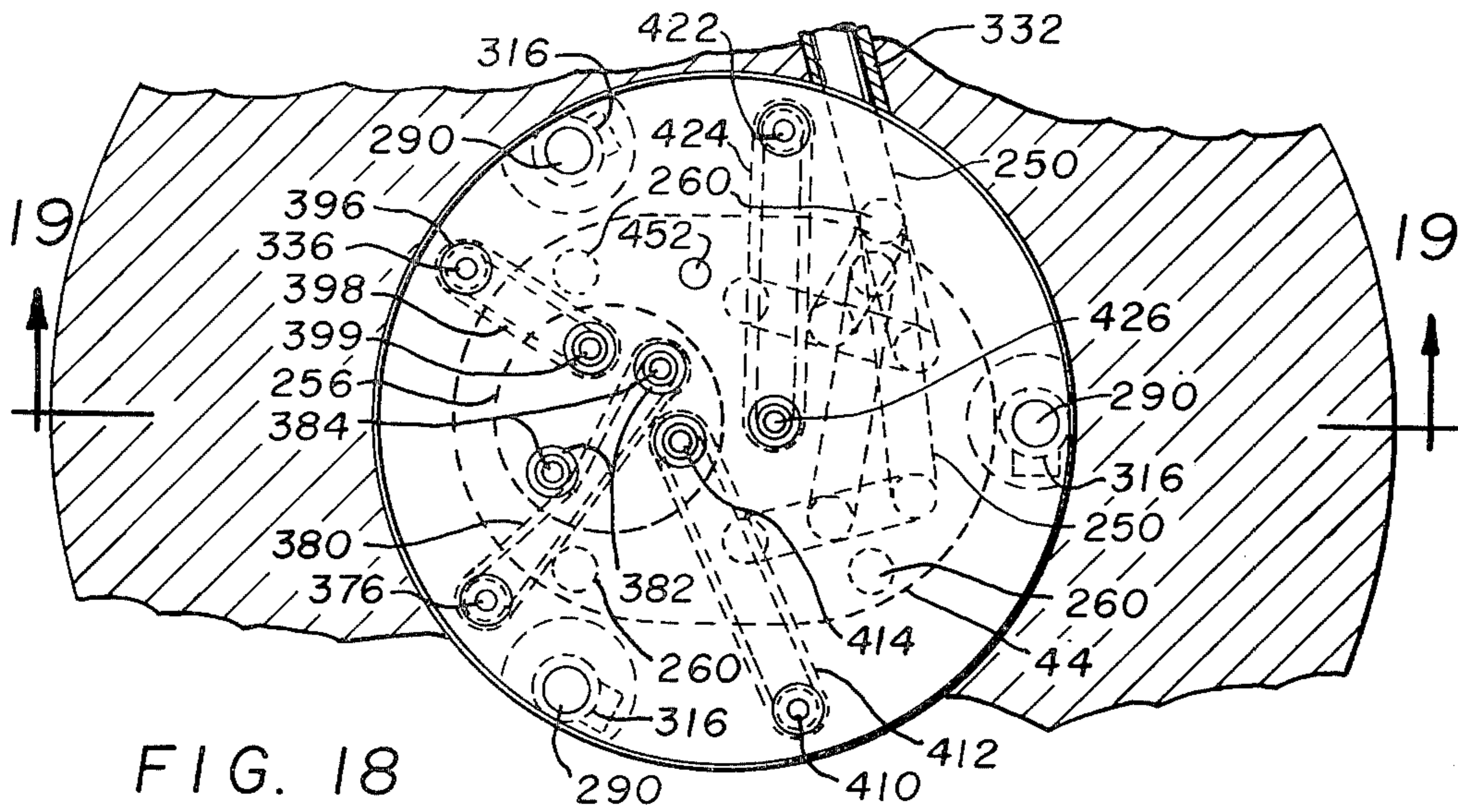


FIG. 18

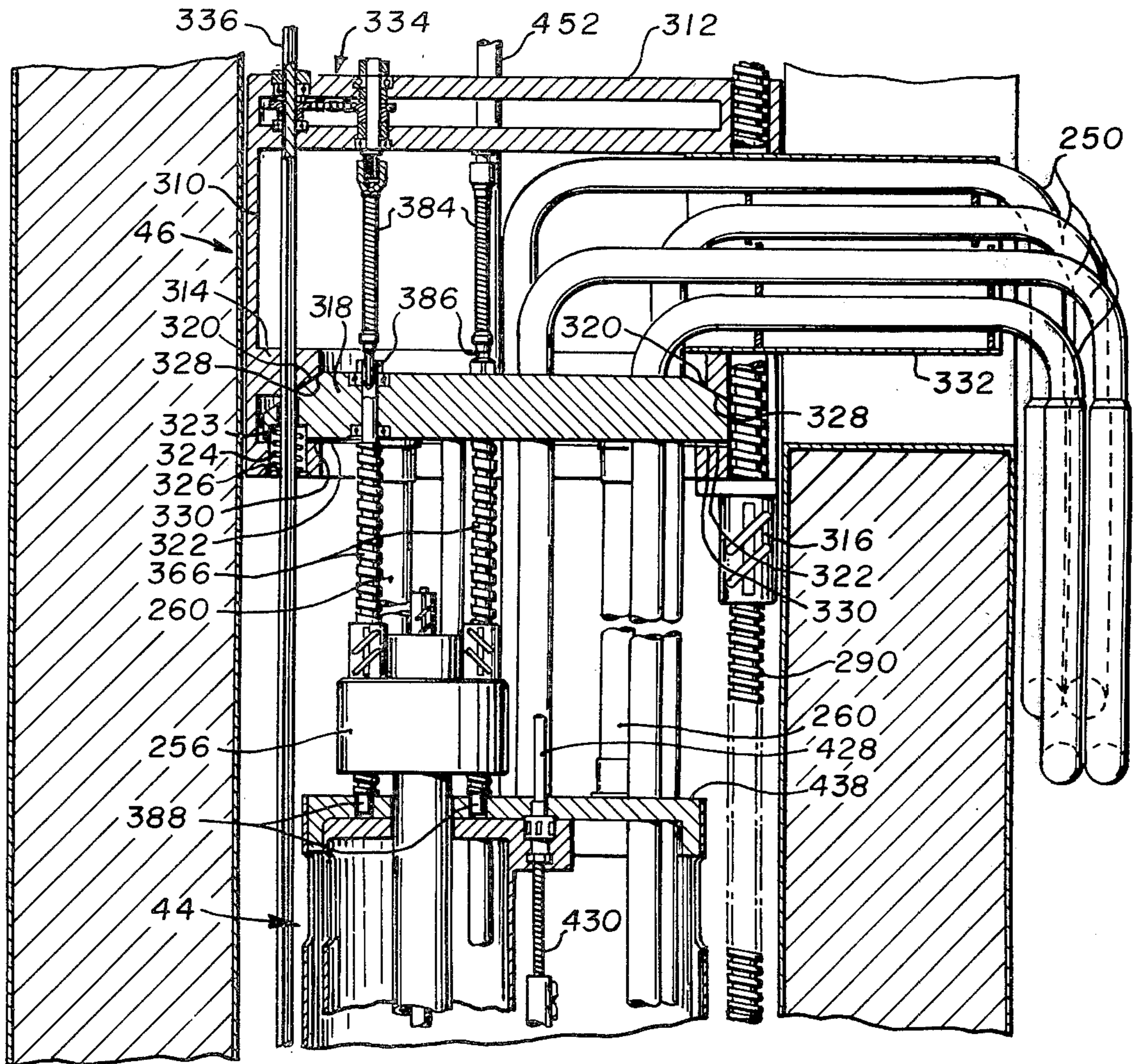


FIG. 19

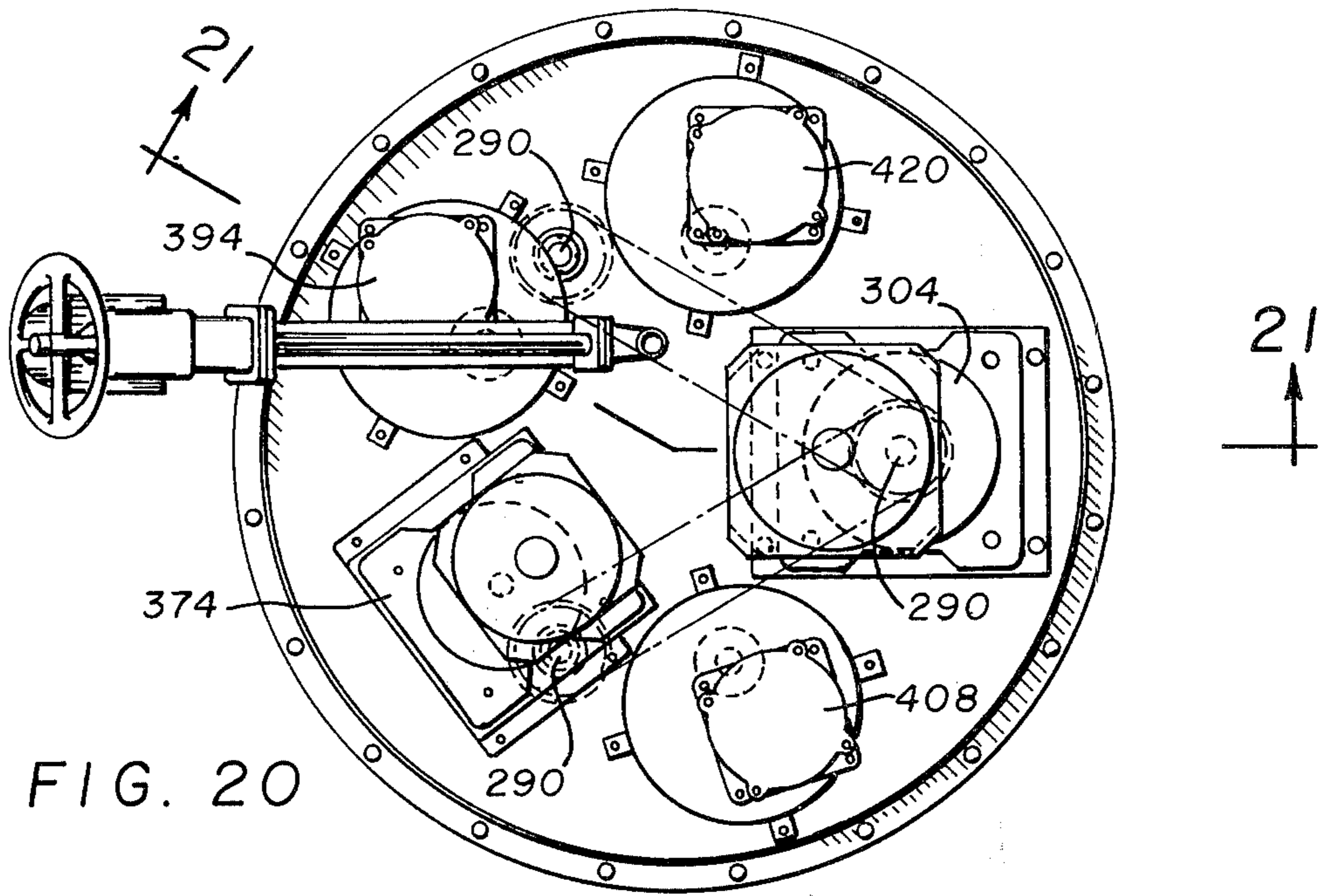


FIG. 20

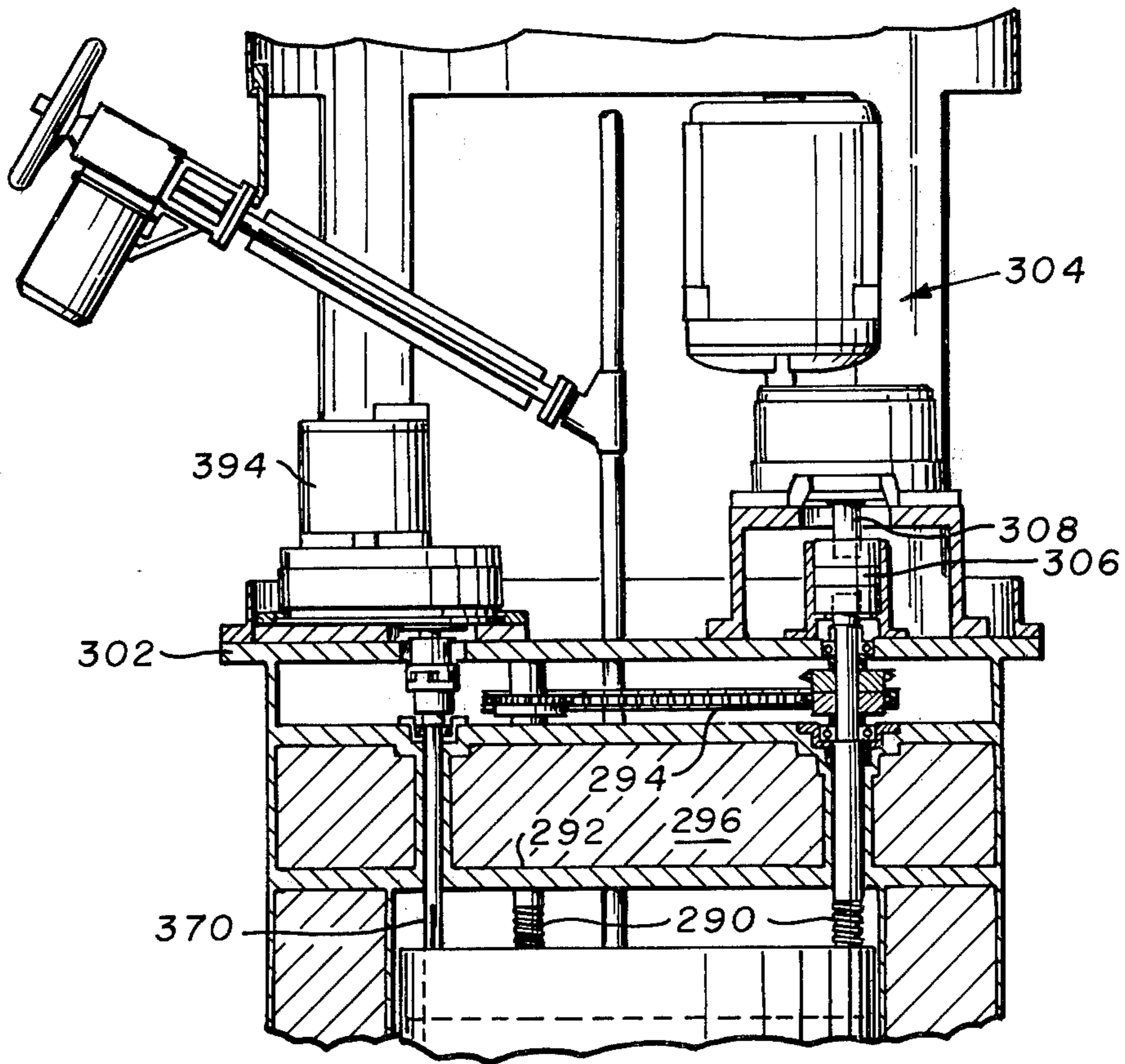


FIG. 21

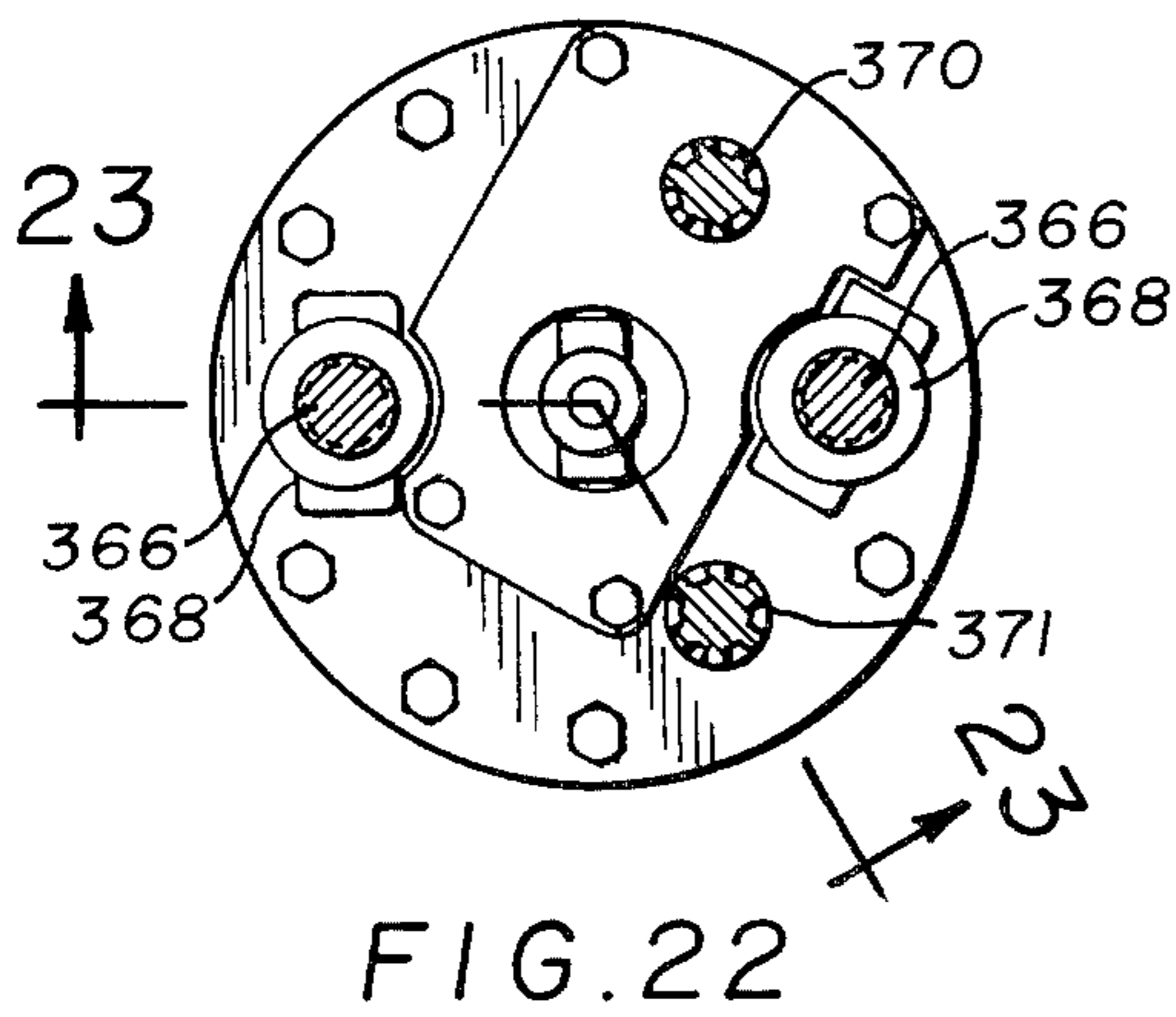


FIG. 22

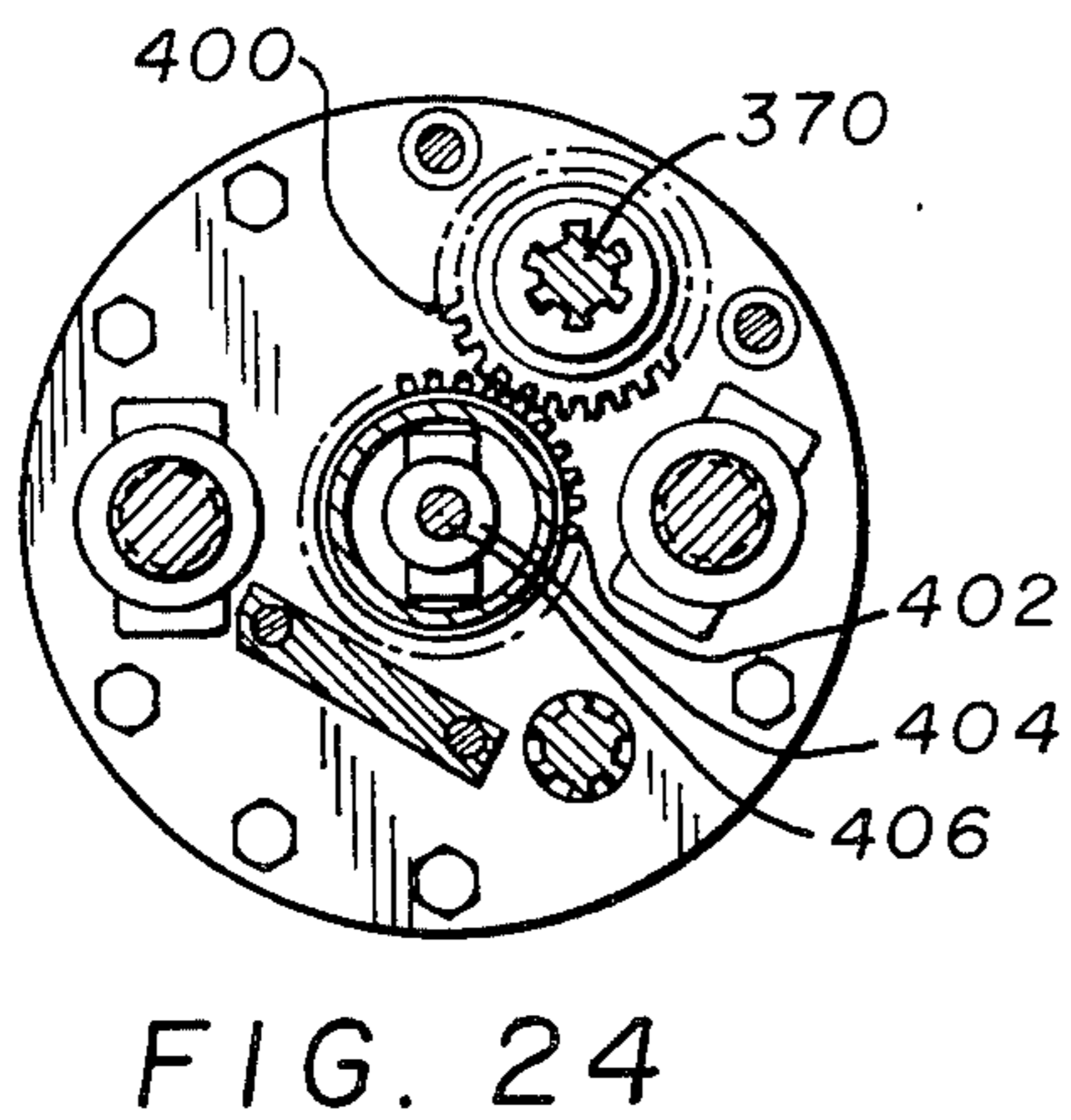


FIG. 24

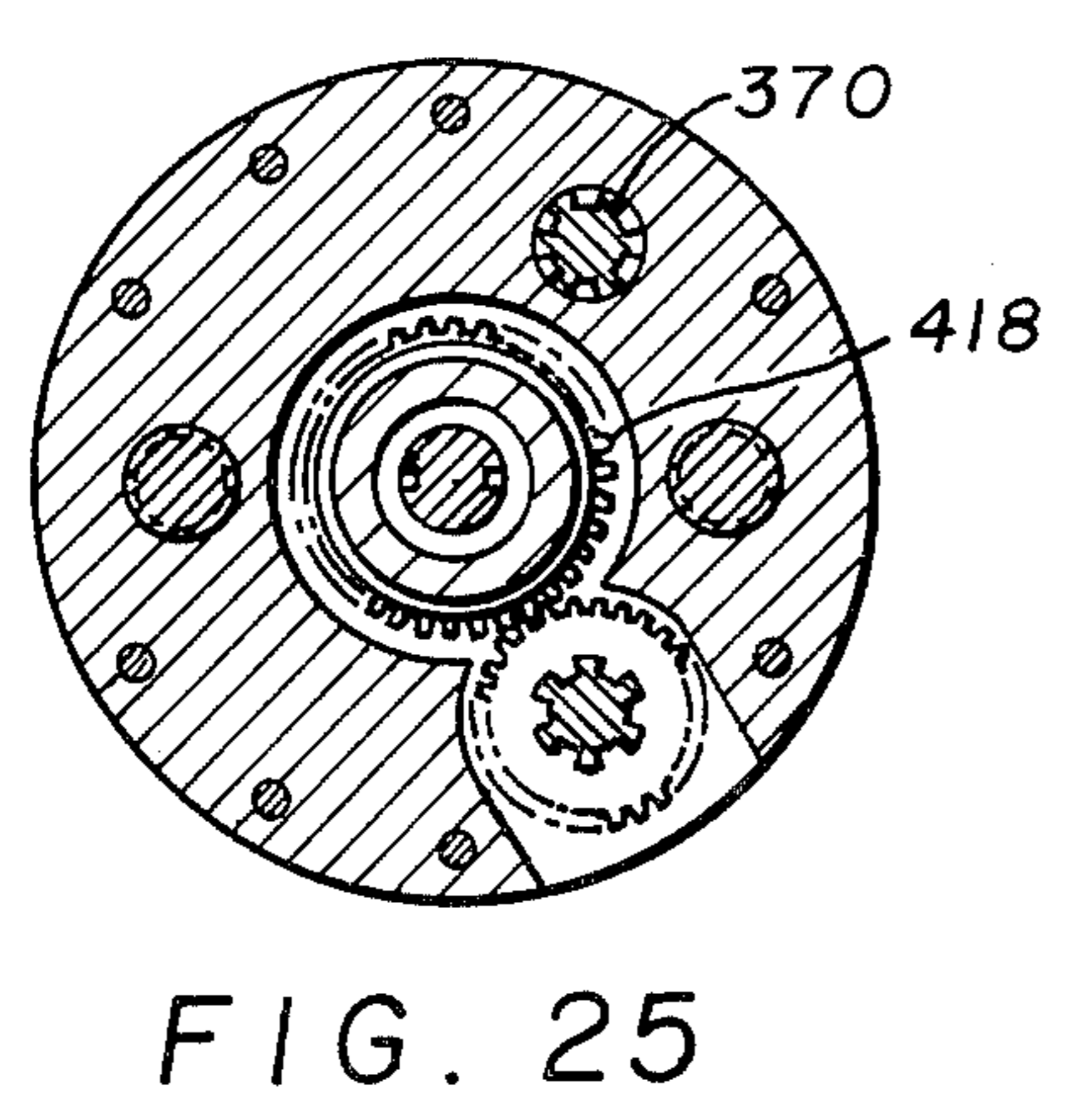


FIG. 25

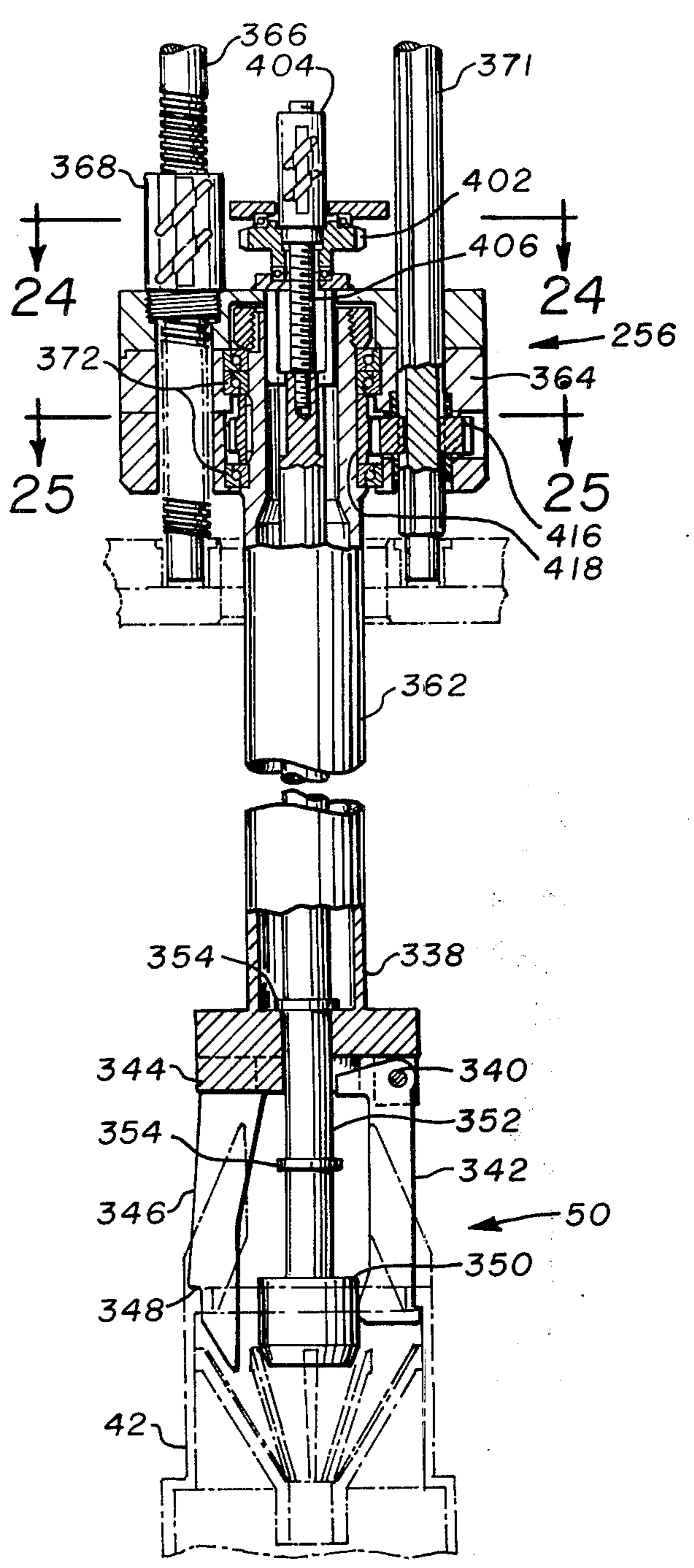


FIG. 23

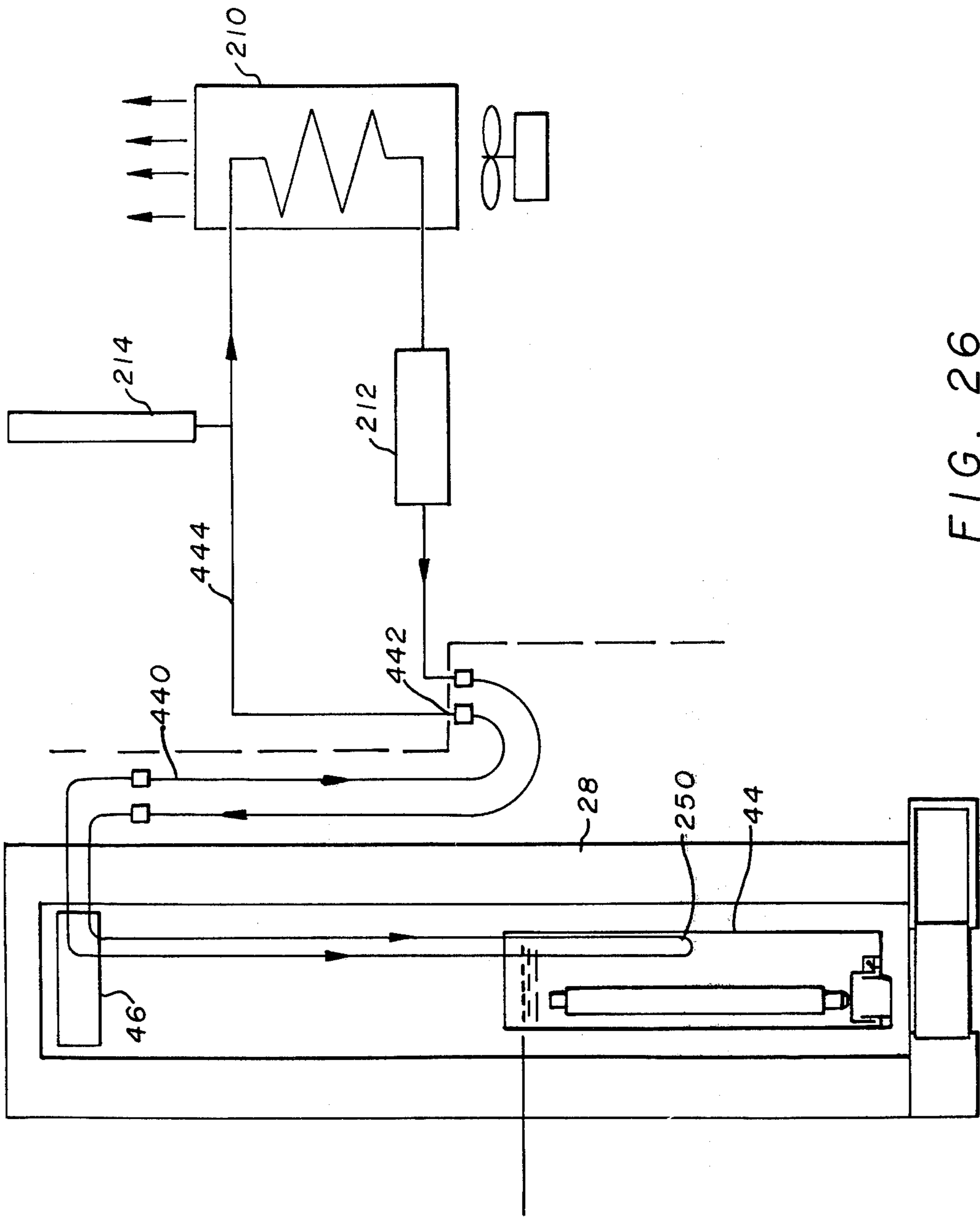


FIG. 26

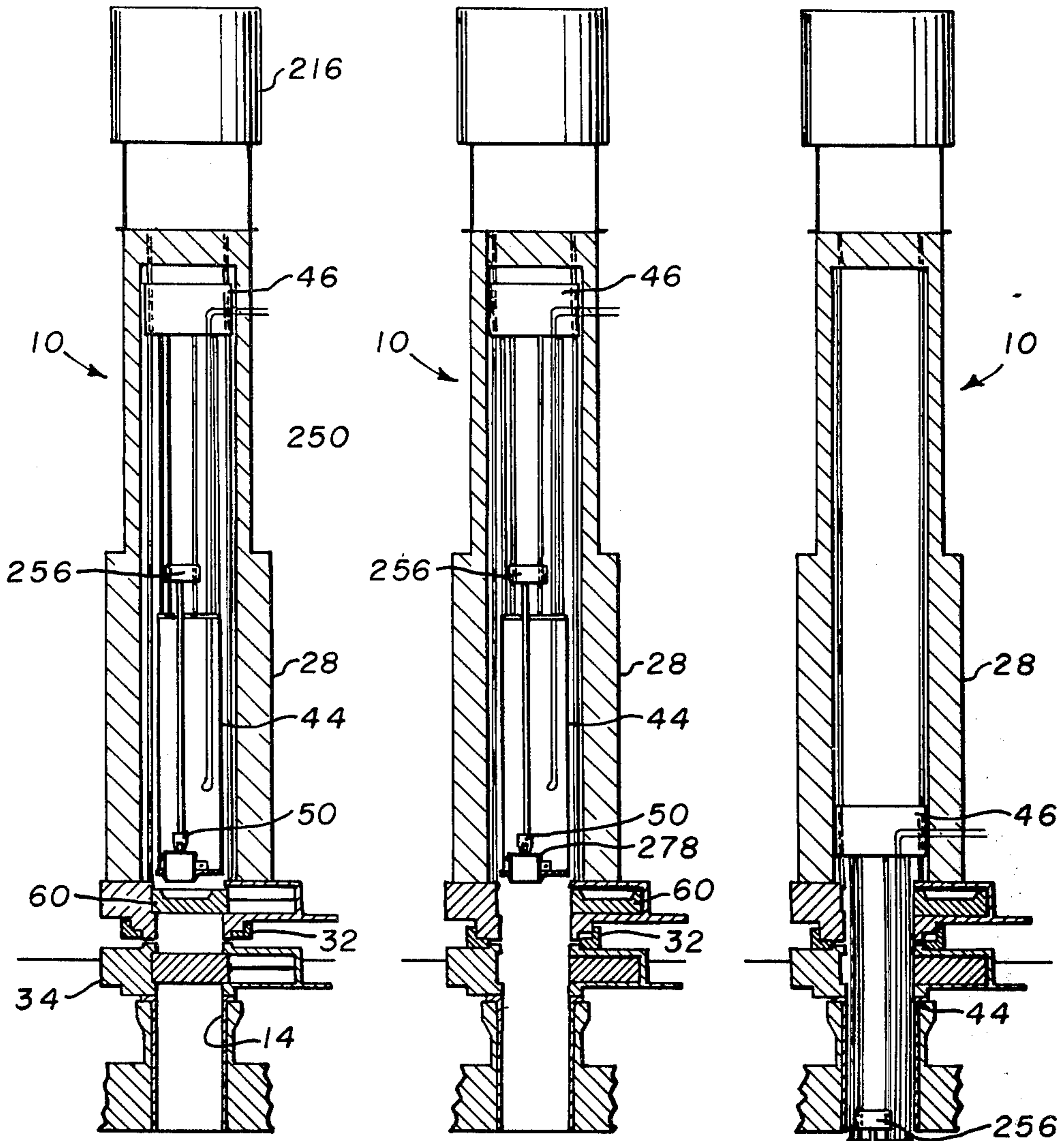


FIG. 27a

FIG. 27b

FIG. 27c

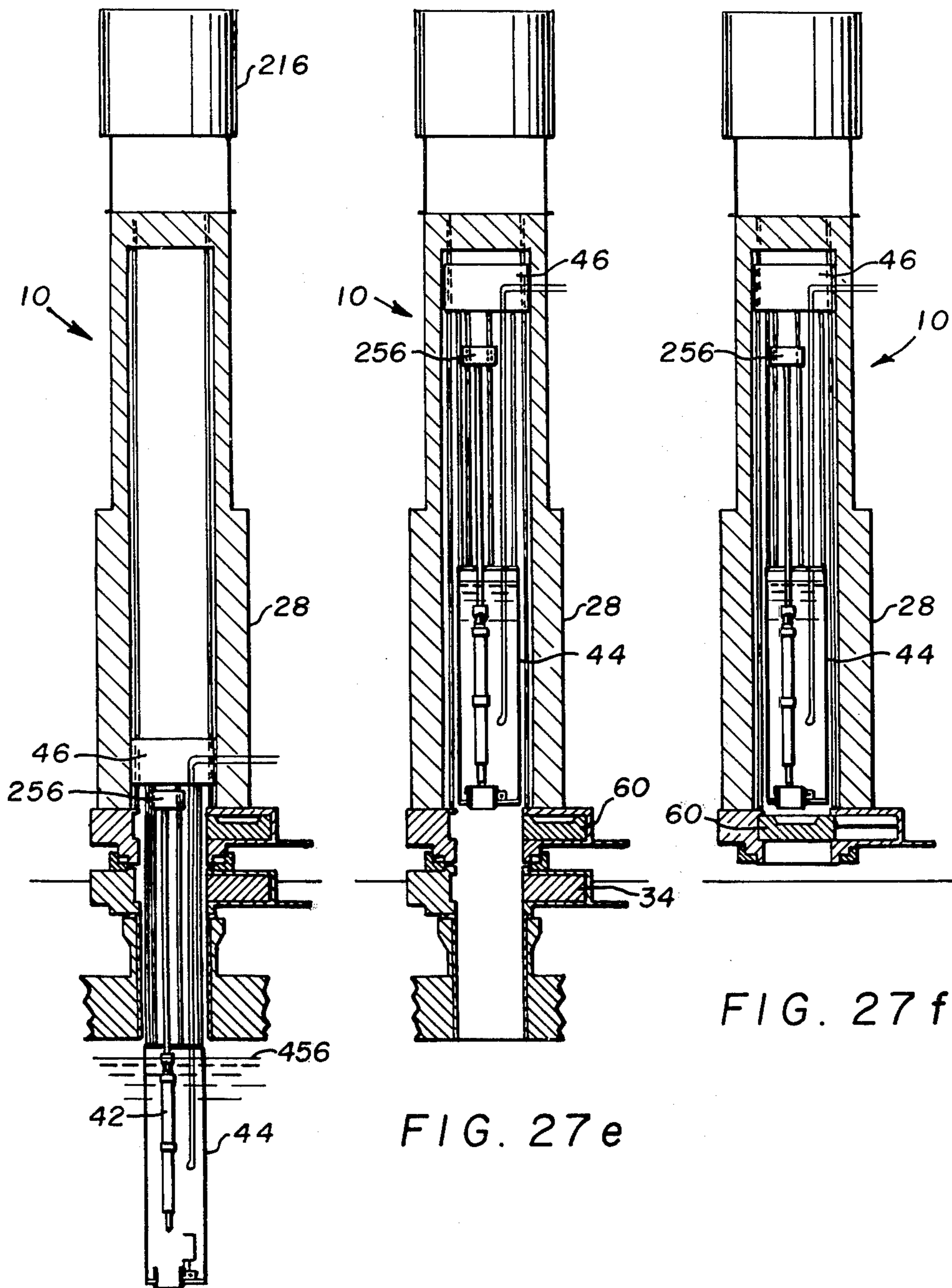


FIG. 27d

FIG. 27e

FIG. 27f

NUCLEAR FUEL HANDLING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to nuclear reactors and more particularly to an apparatus for removing spent fuel from a liquid metal cooled nuclear reactor.

2. Description of the Prior Art

In any nuclear reactor which is intended to operate over an extended period of time such as a reactor which is to be utilized for the generation of electrical power, the reactor facility should be constructed for removal and disposal of used or spent fuel elements and for refueling of the reactor with new fuel elements. Such installations generally include reactor vessels having one or more access ports enabling insertion and removal of fuel elements and other equipment. In addition prior art installations have included some form of temporary storage facility, within the reactor vessel, adjacent the core, for new fuel elements which are to be loaded into the reactor core and for spent fuel elements which are removed from the core. In order to provide such a facility it is necessary that the reactor vessel be made considerably larger than the core, an expensive requirement. Such installations also generally require a plurality of fuel transfer cups in which spent fuel elements are temporarily stored until a separate machine is used to remove them from the reactor. This removal cannot take place until the fuel assemblies have cooled considerably or, alternatively, the separate machine must be provided with a heat removal capability.

SUMMARY OF THE INVENTION

The present invention relates to a fuel handling machine for a liquid metal cooled nuclear reactor which couples to the reactor head, reaches into the reactor and grasps and withdraws the selected fuel assembly directly into the machine and transports the spent assembly to a remotely located decay tank. This operation is achieved while preventing exposure of the surrounding environment to contaminated gases or particles incident to opening of the reactor, and while maintaining the temperature of even the hottest spent fuel subassembly below a predetermined maximum level.

The fuel handling machine comprises an outer barrel upon and within which all subassemblies are mounted. The barrel is mounted for horizontal motion in two perpendicular directions and may be rotated to any desired position. The machine cooperates with a centering and isolating device to enter the reactor vessel and align itself with the subassembly schedules for removal. The shield skirt, a circular ring of shielding material extending from the lower end of the barrel, is lowered until it seals against the reactor and provides a sealed shielded passage from the reactor to the interior of the handling machine. A handling tube which is supported from an articulated joint is lowered from the interior of the barrel into the reactor. The handling tube is guided into alignment with the selected spent subassembly by engaging the centering and isolating device. A closure valve at the lower end of the handling tube is opened to permit a gripper assembly to reach into the core, latch onto and withdraw the spent subassembly into the handling tube. Closing the closure valve converts the handling tube to a sodium filled pot. The closure valve integrity is assured by a novel sealing

arrangement (not a part of the present invention). A backup emergency sodium supply is provided to maintain an adequate sodium level if a major leak develops in the handling tube as the machine is transported between the reactor vessel and the decay tank.

A closed loop, forced flow, NaK cooling system having a cooling coil in the handling tube sodium and an NaK-to-air heat exchanger mounted on the outside of the outer barrel removes decay heat from the handling tube and transfers it to the operating room atmosphere.

The handling tube is raised completely into the outer barrel by a ball-screw drive arrangement, whereupon valves at the bottom of the barrel and at the reactor access port are closed. Raising the shield skirt uncouples the machine from the reactor permitting the machine to be transferred to the decay tank where the spent subassembly is deposited.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view showing the handling plug/spreader assembly and spent fuel handling machine in operative engagement with the nuclear reactor;

FIG. 2 is an enlarged view showing details of the handling plug/spreader assembly and the floor valve installed in the reactor;

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 2;

FIG. 4 is an enlarged view of the spreader assembly;

FIG. 5 is a sectional view of the spreader coupling taken along the line 5—5 of FIG. 4;

FIG. 6 is an exploded isometric view of the spreader coupling;

FIG. 7 is a sectional view taken along the line 7—7 of FIG. 4;

FIG. 8 is a plan view of a reactor core and has an upper and lower portion showing two camming tubes in different positions with respect to selected fuel subassemblies;

FIG. 9 is a sectional view taken along the line 9—9 of FIG. 8;

FIG. 10 is a sectional elevation view of the floor valve installed on the handling plug;

FIG. 11 is a sectional view showing the floor valve drive and spreader drive mechanism, taken along the line 11—11 of FIG. 10;

FIG. 12 is a sectional view taken along the line 12—12 of FIG. 11;

FIG. 13 is a sectional elevation view of the spent fuel handling machine;

FIG. 14 is a sectional view taken along the line 14—14 of FIG. 13;

FIG. 15 is a sectional view taken along the line 15—15 of FIG. 14;

FIG. 16 is a sectional elevation view of the handling tube assembly;

FIG. 17 is a plan view of the handling tube assembly;

FIG. 18 is a plan view of the gripper carriage assembly;

FIG. 19 is a section taken along the line 19—19 of FIG. 18; certain liberties have been taken with this Figure for the purpose of facilitating description of the invention, as is explained in the specification which follows;

FIG. 20 is a plan view of the drive mechanism area atop the fuel handling machine;

FIG. 21 is a sectional view taken along the line 21—21 of FIG. 20;

FIG. 22 is a plan view of the gripper carriage assembly;

FIG. 23 is a sectional view taken along the line 23—23 of FIG. 22;

FIG. 24 is a sectional view taken along the line 24—24 of FIG. 23; FIG. 25 is a sectional view taken along the line 25—25 of FIG. 23;

FIG. 26 is schematic of the fuel handling machine and related cooling systems;

FIGS. 27a—f are a series of views showing the sequential operation of the fuel handling machine.

DESCRIPTION OF THE PREFERRED EMBODIMENT

General Arrangement of Refueling Apparatus

Referring to FIG. 1, spent fuel handling machine 10 is shown positioned above the reactor core 12 and coupled to an access port 14 in the reactor closure head 16. The handling machine is supported in this position by the trolley 18 which is mounted for linear translation on tracks 20 provided on the gantry 22 which in turn is mounted on suitably supported tracks 24 for motion in a direction perpendicular to the trolley.

The attachment of the handling machine 10 to the trolley 18 is accomplished through a mounting ring 26 which is integrally attached to the outer barrel 28 of the handling machine and which is received in a circular bearing 30 (see FIG. 13) carried by the trolley so that the entire handling machine may be rotated about its longitudinal axis. The lower end of the handling machine includes a shield skirt 32 which sealingly engages a floor valve 34 which rests upon and seals with the upper surface of a handling plug 36. The handling plug 36 is contained within the reactor access port 14 and has extending downwardly therefrom a hollow structural shroud 38 which has attached to its lower end a radially floating spreader assembly 40 for engagement with the upper end of one of the subassemblies 42 which make up the reactor core. When inserted into the core the spreader isolates the desired fuel subassembly to permit easy withdrawal of the subassembly from the core.

The handling machine outer barrel 28 contains there-within a fuel subassembly handling tube 44 which is mounted through the handling tube carriage 46 for vertical displacement downwardly through the access port 14 to the interior of the reactor where it is brought into alignment with the selected subassembly by engaging the upper end 48 of the spreader assembly 40. A gripper assembly 50 mounted for vertical motion with respect to the handling tube carriage 46 is then lowered downwardly through an open closure valve 52 at the end of the handling tube where it engages the upper end of the selected fuel subassembly. The gripper with the fuel subassembly attached is then raised into the handling tube 44, the closure valve 52 closed and the entire subassembly raised up into the outer barrel 28. The lower end of the outer barrel includes an isolation valve 60 which is closed upon withdrawal of the handling tube from the reactor into the barrel so that the handling machine may be transported by use of the gantry 22 and trolley 18 to a remotely located decay tank (not shown).

Handling Plug/Spreader Assembly

The handling plug/spreader assembly, shown in detail in FIG. 2, is designed to facilitate the insertion and removal of fuel subassemblies into and from the reactor core. The core spreader includes a camming tube 56 which is capable of locating a given core position and guiding the fuel handling machine handling tube into alignment with that position.

Referring still to FIG. 2, the handling plug/spreader assembly 54 consists of three subassemblies: the floor valve 34; the handling plug 36; and the core spreader assembly 40.

Looking now at FIG. 3, the handling plug 58 is a wedge shaped section shaped to fit into an access port 14 in the top of the reactor closure head. In a typical arrangement the access port 14 may be the opening left in the closure head of a reactor when a similarly shaped control rod island is removed. The rotating plug may be part of a double eccentric rotating plug system for positioning the reactor access port over the various core positions. Such double rotating plug arrangements are well known in the art as exemplified by the arrangement shown in U.S. Pat. No. 3,054,741, entitled "Nuclear Reactor Control Assemblies" by Tatlock et al. The insertion of the handling plug/spreader assembly into the reactor will be more fully described in connection with the description of the operation of the refueling machine.

An obround opening 62 in the handling plug 58 is provided to permit passage therethrough of the handling tube from the fuel handling machine. An elongated structural tube or shroud 38 is attached to and suspended from the bottom of the handling plug 58 and extends downwardly therefrom to support the core spreader 40 through two ball screws 64. Referring to FIG. 10 the handling plug 36 is supported, and its penetration into the access port 14 limited, by the engagement of a flange 66 at the upper end of the plug with the upper face 68 of the rotating plug. The upper face 70 of the handling plug mates with the lower surface 72 of the floor valve 34 and a gas-tight seal is effected therebetween by a double O-ring sealing arrangement 74. FIG. 2 shows an elongated shield plug 76 inserted within the obround opening 62 in the handling plug 36. This plug 76 serves as a temporary shield before the installation of the floor valve 34 and is removable remotely after the floor valve is secured in position.

Referring to FIG. 4, the core spreader assembly 40 is shown in detail in engagement with the reactor core 12 so as to isolate a typical fuel assembly 42 to facilitate removal of the assembly from the core. The spreader assembly includes the hexagonal camming tube 56 which is mounted within the spreader housing 78 in a manner to permit limited radial movement of the tube with respect to the housing. The mounting of the camming tube 56, which is essentially an inverted Oldham coupling, is comprised of three plates: the upper plate 80, which is a radial extension of the camming tube; the base plate 82; and the key plate 84, which acts as the connecting link between the upper plate and the base plate. These plates are shown in detail in FIG. 6, and their interrelationship will be described in more detail below.

Referring back to FIG. 4, the base plate 82 is mounted for rotational motion about the centerline 86 of the spreader assembly 40 through a bearing 88 which is supported by the lower end 90 of the spreader

housing. A segment of the outer periphery of the base plate contains gear teeth 92 which are adapted to engage mating teeth provided on a pinion 94 (see FIG. 5). The pinion 94 is driven by gear teeth on the angular alignment shaft 98 which extends upward through the elongated shroud 38 and engages a suitable rotational drive arrangement 100 carried by the floor valve 34 (see FIG. 11). The lower end 102 of the angular alignment shaft is supported in a bushing 104 carried by the spreader housing 78. Rotation of the angular alignment shaft 98 causes the base plate 82 to rotate through a maximum angle of 60°. Such a degree of rotation permits the hexagonal camming tube 56, which rotates with the base plate, to be angularly aligned with a selected hexagonal fuel subassembly at any core location.

Referring again to FIG. 6, the key plate 84 is annular in shape and contains two sets of keyways, on opposite sides of the plate and rotated 90° from one another. The first set of keyways 106 is on the lower side of the plate and is engaged by keys 110 formed integrally with the base plate and extending upwardly therefrom. The key plate 84 is thus permitted a small degree of motion along the longitudinal axis of the keyways 106. The upper plate 80 of the camming tube 56 is in turn supported on the upper surface of the key plate. Key extensions 112 of the upper plate 80 engage the second set of keyways 108 and permit limited motion of the camming tube 56 along the second key axis. The above described arrangement permits the camming tube 56 to freely seek and isolate the desired core position without causing undesirable bending stresses in the shroud 38 and other spreader support structure. The interaction of the camming tube 56 with the core will be described with reference to FIGS. 4, 8, and 9. FIG. 4 shows the tube in its desired final position with respect to the core position into which a subassembly is to be removed or inserted. The hexagonal camming tube 56 is in contact with each of the fuel subassemblies 114 adjacent to the core position of interest and, because the internal dimensions of the camming tube 56 are larger than the outer dimensions of the fuel subassembly 42, there exists an all-around clearance 120 between the inside of the camming tube and the selected fuel subassembly. This clearance 120 permits unrestricted insertion and withdrawal of subassemblies from the core position. Referring still to FIG. 4, each fuel subassembly (42, 114) is provided with an upward facing shoulder 122. In the event that an adjacent fuel subassembly is caused to move upward when a particular subassembly is being withdrawn, the upward movement will be limited to a short distance by the engagement of the shoulder 122 with the end of the camming tube 56.

Turning now to FIGS. 8 and 9, the interaction of the camming tube 56 with the core, as the camming tube is being inserted into the core, will be described. FIG. 9 and the upper portion of FIG. 8 show a camming tube 56 substantially misaligned from the subassembly 42 to be removed. As best shown in FIG. 9, each of the fuel assemblies 42 includes six symmetrically arranged, inwardly inclined tabs 116 at their upper ends. The symmetrical arrangement of these tabs 116 co-act to form a camming surface which when engaged by the camming tube 56 cause the tube to move into axial alignment with the selected subassembly. The lower end 118 of the camming tube is chamfered on the outside edge to further facilitate guidance of the camming tube into alignment with the selected fuel subassembly. As the tube 56 is lowered toward the subassembly the

chamfered lower edge 118 of the tube engages the inwardly extending tabs 116 of several adjacent subassemblies. As a result, as the tube is lowered into the core it is caused to move laterally to become axially aligned with the fuel subassembly and to assure the fully engaged position as shown in the lower portion of FIG. 8.

As was pointed out above, the core spreader 40 is attached to an elongated shroud 38 by means of two ball screws 64. Referring to FIG. 4, these ball screws are attached to the spreader housing 78 and extend upwardly through the shroud 38 where they are suitably supported by a series of bosses 124 on the inside of the shroud through which the ball screws 64 are journaled. Referring to FIG. 7, it is seen that the two ball screws 64 are disposed symmetrically on either side of the spreader longitudinal axis 86. A third rod or rail 128 is provided to act as a guide only and extends only partially into the shroud.

Turning now to FIG. 12, the upper end of each of the ball screws 64 engages a ball nut 130 which is enclosed in a protective sleeve 132 attached to the lower face 134 of the handling plug 36. This sleeve 132 permits controlled rotation of the nut 130 within it, while restraining it from axial movement. Rotation of the ball nuts 130 thus imparts axial movement on the ball screw shafts 64. A recess 136 is provided in the handling plug 36 above the ball nut to receive the ball screw shaft 64 when it is in the up position. The ball nuts 130 are driven by two stepping motors 138 mounted on a platform 140 extending from the floor valve (see FIG. 11). The axis of rotation of the motor drive line 142 is changed from horizontal to vertical through a bevel gear set 144 contained within the floor valve 34. The vertical drive line 146 couples to a second vertical line by means of a spline coupling 148 at the interface between the handling plug 36 and the floor valve 34. The spline coupling 148 is comprised of a spring-loaded sliding spline 150 in the floor valve section of the drive line and a splined one-directional, or antirun back device 152 which the sliding spline 150 engages, and which is located in the handling plug 36. The lower end of the handling plug portion of the drive line 153 carries a small gear 154 which engages mating circumferential gear teeth 156 carried by the ball nut 130.

Remote actuation of the motors 138 thus causes the ball screws 130 to move vertically up or down to cause withdrawal or insertion, respectively, of the spreader assembly 40 with respect to the reactor core. The vertical travel of the spreader is limited by hard stops 158 on the lower portion of the ball screw shafts and the third rail 128. These stops 158 provide for sufficient vertical movement to permit full insertion and withdrawal of the spreader clear of the core, while at the same time preventing damage to the spreader and/or core which might result from attempting to force the spreader farther than necessary into the core.

The Floor Valve

Referring to FIG. 10 the floor valve 34 fits over and attaches to the handling plug to complete the handling plug/spreader assembly 54. During refueling the upper surface 160 of the floor valve interfaces with the refueling machine to form a hermetically sealed passage through the handling plug into the reactor. When the valve is closed it provides a barrier of lead shielding for personnel protection. The floor valve 34 is basically a heavily shielded gate valve. The valve disc 162 is ta-

pered on its lower face 164 to mate with a similarly tapered valve seat 166. This protects the O-ring lower sealing element 168 from damage when the disc is moved to close or open the passage. The valve body 170 is otherwise a hermetically sealed unit with connections 176 provided for purging the body of the valve with clean argon.

Referring to FIGS. 10 and 11 the valve disc 162 is mounted on rails 178 and rides on a series of ball bushings 180. Motive force to operate the valve is provided by a ball screw drive arrangement 182. The drive motor 184 is mounted outside of the valve 170 and drives, through a one-directional coupling 186, a ball screw shaft 188. The shaft 188 and motor 184 are axially stationary and engage a ball nut 190 attached to the valve disc 162. Upon actuation of the motor 184 the disc is caused to be inserted or retracted, with the ball screw shaft 188 passing into a longitudinal cavity 192 within the disc 162 when the valve is fully open.

Spent Fuel Handling Machine

The spent fuel handling machine 10 is designed to remove spent fuel subassemblies directly from the reactor core 12 to the decay tank (not shown). During this transfer, the spent subassemblies are maintained immersed in liquid sodium within a handling tube. Referring to FIG. 1, the machine 10 is located for movement on X-Y coordinates by moving with the gantry crane 22 and its associated trolley 18. The machine is rotatably mounted to the trolley 18 through a mounting ring 26 and is rotated with respect to the crane and trolley by actuation of a drive motor 194 which engages circumferential gear teeth 196 on the outer periphery of the mounting ring 26 (see FIG. 13).

The handling machine works with the handling plug/spreader assembly to enter the reactor vessel and align itself with the subassembly scheduled for removal. Referring to FIG. 13 the main structural component of the handling machine is a vertically extending shielded cylinder 28 which will be hereinafter referred to as the outer barrel. All systems and components of the handling machine are supported from the outer barrel. The mounting ring 26 through which the machine is supported by the trolley is an integral part of the outer barrel. A large bearing 30 is disposed between the mounting ring and the trolley to facilitate rotation of the machine to bring it into alignment with the access port of the reactor. To cover all core locations the outer barrel drive 194 is provided with a 360° rotation capability which is controlled by a pre-programmed control system.

The outer barrel 28 is divided into two regions because of radiation shielding requirements. The lower end 200 is supplied with shielding equivalent to about 13" of lead. The upper end 202 is shielded with about 6" of lead. Referring to FIGS. 14 and 15, the shielded walls of the outer barrel are bisected by a vertically extending slot 204 connecting an adjacent shielded flexible hose cavity 206 to the interior of the outer barrel. This cavity houses loops of flexible hoses 208 used to bring various service lines from the exterior of the outer barrel 28 to the internal assemblies. Among the services required are NaK lines for cooling loops, an argon line, and instrumentation lines for monitoring and controlling operation of the fuel handling machine. Two NaK-to-air heat exchangers 210 are mounted on the outside of the outer barrel to dump decay heat removed from inside the handling tube into the operat-

ing room atmosphere. Other components which are mounted on and supported by the outer barrel include sodium pumps 212 and surge tanks 214 for the two coolant loops, an emergency sodium supply tank 216, and motors and associated drives 218 for the various mechanical manipulators. Each of these components and systems will be subsequently described in greater detail.

Referring to FIG. 13, there are integrally formed with the lower end 200 of the outer barrel an isolation valve housing 220 and a stationary portion 222 of a shield skirt assembly extending down from the isolation valve housing. The isolation valve 60 provides shielding and gas sealing at the bottom of the outer barrel during transport of the machine and also provides sodium containment in the event of sodium leakage from the handling tube 44 contained within the outer barrel 28.

Referring still to FIG. 13, the isolation valve 60 is basically a heavily shielded gate valve virtually identical in design to the floor valve 34. The valve disc 224 is tapered on its lower surface to mate with a similarly tapered valve seat 228. This arrangement minimizes the possibility of damage to the sealing element, which comprises an O-ring 230 embedded in a groove in the valve seat, during operation of the valve. The valve disc 224 is sealed on its upper face by an inflatable seal 236 which seals against the valve disc. The interior of the valve body is, except for the opening covered by the valve disc, hermetically sealed and includes gas connections (not shown) for purging with a clean inert gas such as argon.

The mounting and actuation apparatus 234 of the isolation valve disc 224 is identical to that for the floor valve 34 and will not be described in detail. The upper side of the isolation valve disc is hollowed out 238 to permit placement of a drip pan 240 which is provided to collect small sodium drips from the handling tube 44 contained within the outer barrel 28. The drip pan is designed to serve as a backup to the handling tube closure valve 52. If a leak develops in the valve, the handling tube is lowered into the drip pan 240 which is contoured to provide a plug into which the end of the handling tube 44 can be inserted. This engagement will be understood more fully following the complete description of the handling tube and closure valve assemblies.

As pointed out above, the stationary portion 222 of the shield skirt extends downward from the isolation valve body 220. This portion of the skirt comprises an annular ring having essentially an inverted L-shaped cross section. The movable portion of the shield skirt 244 comprises a movable ring section mating with and guided by the stationary section. The movable section has an L-shaped cross section and mates with the stationary section at two surfaces 246, 248. Double O-ring type seals are provided at each of these mating surfaces. Vertical motion of the movable section is caused by a series of four ball screws supported from the stationary section and driven by a drive motor 252 attached to the isolation valve housing 220. Details of the drive system are not shown in the drawing. In operation, the handling machine 10 is positioned just above the floor valve 34 of the spreader assembly and the shield skirt lower section 244 is actuated to move downwardly to form a seal with the floor valve 34 through double O-rings 161 (see FIG. 10) in the upper surface of the floor valve.

Internal Assemblies

The internal assemblies include all mechanisms and components contained within the shielded outer barrel. Among these, generally, are the handling tube 44, the handling tube carriage 46, the gripper 254 and gripper carriage 256 and the drive mechanisms.

The handling tube assembly is shown in FIG. 13 in its at rest position within the outer barrel, and in more detail in FIGS. 16 and 17.

The handling tube 44 is an elongated obround vessel designed to accommodate a spent fuel subassembly; it further includes cooling coils 250 to remove decay heat given up by the subassembly, and a closure valve assembly 52 to contain liquid sodium within the tube. The handling tube is supported at its upper end by the handling tube support plate 258, which in turn is supported, from above, through four columns 260 attached to the handling tube carriage assembly 46, which will subsequently be described in considerable detail. The lower end of the handling tube contains the closure valve seat 262 and an alignment nozzle 264. The alignment nozzle is tapered inwardly on its outer edge and is sized to facilitate engagement with the upper end 48 of the upper plate/camming tube component to the spreader assembly 40 when the handling tube 44 is lowered into the reactor core.

Inside the handling tube and also suspended from the handling tube support plate 258 is the parking tube assembly 268. The parking tube 268 has attached to its lower end the necessary structure to guide and operate the closure valve disc 278 and mechanism. This structure includes a pair of spaced vertically extending gear racks 272 and suitable journal type guide means 274 for the valve actuator shaft 276. The closure valve disc is supported by a yoke 280 having a geared sector which engages the rack 22 and is restrained and guided in its travel by the gear rack and guides mounted on the parking tube. The valve disc 278 is operated by a ball screw shaft 282 which attaches to the valve actuator 276 and in turn to the yoke 280. When the ball screw shaft is drawn upward the valve disc, which includes an integrally formed downwardly extending skirt portion 284, is raised slightly upwardly to provide clearance and is then caused to swing laterally out of the way of the passage-way 285 into the handling tube 44. The valve 278 is shown in its open position in FIGS. 27c and d of the series of figures showing the operating sequence of the present invention. The details of construction and operation of the closure valve are more specifically shown and described in a copending application entitled "Anti-Leak Closure Valve" of C. Andrea filed on even date and assigned to the same assignee as the present invention.

Referring back to FIG. 16, the parking tube proper begins at a position 286 above the valve seat 262 sufficient to permit unobstructed operation of the valve and extends up to and is attached to the handling tube support plate 258. The upper end of the parking tube is supplied with flow holes 288 to permit free circulation of liquid sodium heated in the parking tube by spent fuel decay heat generation.

Handling Tube Assembly

As was indicated the handling tube assembly is supported from above by four columns 260 attached to the handling tube carriage assembly 46. The handling tube carriage in turn is mounted on three ball screws 290

(only one of which is shown in FIG. 13) which extend the full length of the outer barrel and which when actuated cause the entire handling tube assembly to translate vertically within the outer barrel 28. The full range of travel of the handling tube 44 is illustrated by reference to FIGS. 27a and 27c where it is shown in fully withdrawn and fully inserted positions, respectively.

Referring to FIGS. 20 and 21 it is seen that the three ball screws are equally spaced about the carriage and pass through the top 292 of the outer barrel where they engage with a chain drive mechanism 294 which is contained within a disc-shaped compartment 296 positioned above the top of the barrel. The top of this compartment forms a drive mechanism platform 302 which carries the motor gear reducer set 304 which drives the chain drive mechanism 294. An anti-runback device 306 is provided between the gear box output shaft 308 and the ball screw drives 294 to assure that the handling tube carriage 46 will not run down due to gravity in the event of a loss of electrical power.

Referring to FIGS. 18 and 19, the handling tube carriage 46 is comprised of two major components; the outer portion 310 which includes the chain drive support plate 312 and the swivel cage 314 to which the three ball screw nuts 316 which engage the handling tube ball screws 290 are attached; and the swivel plate 318 which is contained by the swivel cage 314 and to which the four columns 260 which support the handling tube assembly 44 are rigidly attached. While the carriage assembly 46 and handling tube assembly 44 are shown in close proximity in FIG. 19 for convenience of illustration, it should be appreciated that the handling tube support columns 260 are quite long, in order to allow engagement of the handling tube 44 with the reactor core when the carriage 46 is in its full down position.

Referring still to FIG. 19, the swivel plate 318 is essentially disc shaped and has a spherical surface 320 on its upper edge. The lower surface 322 of the swivel plate is flat and the plate is supported through a series of die springs 324 disposed between recesses 323 in the bottom of the plate and the base plate 326 of the swivel cage. These springs 324 are sized to lift the swivel plate 318 and handling tube assembly 44 without a spent subassembly inside, from the flat lower surface 322 and to urge the spherical surface 320 into engagement with a mating spherical surface 328 on the upper portion of the cage. The clearance 330 between the lower surface 322 of the plate and the base plate 326 is sufficient to permit a swiveling motion of the swivel plate 318/handling tube 44 assembly with respect to the rest of the carriage 46. This freedom of motion permits the handling tube 44 to accommodate a limited amount of misalignment from the theoretical centerline as it is lowered down through the outer barrel 28 into the reactor and into engagement with the spreader assembly 40. When a spent fuel subassembly is held in the handling tube the weight is sufficient to overcome the upward force of the die springs 324 and causes the swivel plate 318 to seat on the flat surface 322, thus assuring perpendicularity of the tube 44 as it is withdrawn from the core back into the outer barrel 28.

The upper section of the handling tube carriage 46 is attached rigidly to the cage section 314 and provides support for the offset arm 332 which provides support and guidance for the coolant lines 250 and other services such as gas lines which must pass from the flexible hose cavity 206 to service the handling tube assembly.

The upper section of the carriage also serves as a support structure 312 for chain drive power take-offs 334 from the primary splines for the gripper actuation and manipulation of which this shaft identified as 370 is typical. These drive arrangements will be fully described below in connection with the description of the gripper system.

Gripper System

The gripper system is comprised of two major subassemblies, the gripper assembly itself 50 and the gripper carriage 256; the relative position of these subassemblies is simply shown in FIG. 27a.

Referring to FIG. 23, the gripper assembly consists of the body 338 to which are mounted, through pinned connections 340 three gripper fingers 342. The fixed part of the gripper is referred to as the pedestal 344 and comprises three downwardly extending projections 346 which engage the upper end of a fuel assembly 42, as at 348, to provide the proper orientation between the gripper and the subassembly. The gripper actuator includes an enlarged plunger 350 attached to an actuator rod 352. The actuator rod 352 is actuatable in a vertical direction and is stop-limited through stops 354 for proper positioning. When the actuator rod 352 is in the down position (as shown in FIG. 23), the gripper actuator plunger 350 holds the gripper fingers 342 in the engaged position with the extension on the lower outer portion 356 of the fingers 342 engaging the lower surface 358 of a peripherally extending lip on the subassembly. When the actuator rod 352 is in the full up position, the fingers 342 are caused to swivel inwardly to the disengaged position as the lower stop engages the upper arm 360 of the fingers 342. The gripper actuator is mounted to permit free rotation of the actuator rod 352 to minimize friction forces that must be overcome when the gripper, with a subassembly attached, is rotated for fuel rotation or shuffling to another position in the reactor core. The gripper 50 is suspended from the gripper carriage 256 by the gripper support tube 362. This tube is hollow to minimize weight and to permit passage of the actuator rod 352 therethrough to the gripper carriage.

Referring to FIGS. 22 through 25, the gripper carriage 256 is essentially a machine crosshead 364 and is the focal point for the apparatus for performing all of the gripper manipulations required. The raising and lowering of the gripper carriage is accomplished by two ball screws 366 which engage ball screw nuts 368 mounted on the gripper carriage. Two spline shafts 370, 371 energize drive trains in the carriage, one (370) operating the gripper actuator 352 as previously described, and the other (371) for rotating the gripper.

The gripper support tube 362 is mounted in the gripper carriage crosshead 364 on bearings 372 and is free to rotate in relation to the gripper carriage 256. The gripper rotation drive is capable of placing the gripper 50 in angular alignment with the core for all core positions and is also used for performing subassembly rotation.

Drive Mechanisms

The handling machine 10 requires five independent drive trains for operating the internal mechanisms described above. Drive packages for all five of these drives are located on the platform 302 above the shielded outer barrel 28. These drives are in an argon atmosphere at all times and because they are isolated

and shielded from the barrel internal atmosphere permit personnel access to perform maintenance at all times.

Before proceeding with the description of the drive mechanisms a few clarifying comments will be made with regard to FIGS. 18 and 19 of the drawings. FIG. 18, as already indicated, is a plan view of the upper end of the gripper carriage 46 showing the location of all drive shafts and other services which enter the handling tube. The locations of chain drives, the gripper carriage, the handling tube and the coolant lines are also shown in phantom lines.

While FIG. 19 is identified as a section to the view of FIG. 18, certain liberties have been taken in this figure to more clearly illustrate the apparatus. The following modifications have been made in this drawing: The offset arm 332 has been rotated into view along the horizontal section; the gripper actuator spline shaft 370 has also been rotated into view; the gripper carriage 256 and associated drive shafts have been rotated clockwise to bring the two ball screw shafts 366 into alignment with the section line 19-19.

The five drive mechanisms include the handling tube carriage drive, the gripper drive, the gripper actuator drive, the gripper rotation drive and the closure valve drive. The handling tube carriage drive has already been described in connection with the handling tube carriage 46 and as indicated includes the motor gear reducer set 304, an anti-runback device 308, chain drive arrangement 294, and the three ball screws 290.

The gripper drive mechanism provides the motive force to lower and raise the gripper carriage 256. Referring to FIGS. 20 and 21, a motor gear reducer set 374 drives a spline shaft 376, similar to the shaft 336, which extends the full length of the interior of the outer barrel 28. Referring now to FIGS. 18 and 19 again, the shaft identified as 336 is typical of the gripper drive spline shaft and those used in connection with the other similar drive mechanisms. The shaft passes through the swivel plate 318 of the handling tube carriage 46 with sufficient clearance to permit free rotation of the shaft and the necessary swiveling or tilting of the plate. A swivel plate support spring 324 is disposed concentrically about the shaft. The shaft then passes downwardly through the space between the inner wall of the barrel 28 and the outer wall of the handling tube 44.

Still referring to FIGS. 18 and 19, the spline shaft 376 slideably engages a splined chain drive sprocket similar to 378 which is held captive in the chain drive support plate 312 of the handling tube carriage 46. This sprocket, as does 378, rides on the spline shaft, and through a chain 380 drives two other sprockets 382 which are located directly overlying the gripper carriage 256. These sprockets 382 in turn drive a pair of flexible shafts 384 which extend down to the swivel plate 318. At the swivel plate, the flexible shafts 384 engage, through splined connections 386, the gripper drive ball screw shafts 366 which extend down through the gripper carriage 256 and are supported at their lower ends 388 in the top of the handling tube 44. The ball screws 366 engage ball screw nuts 368 which are held captive in the gripper carriage 256. Accordingly, as the ball screws 366 are rotated the gripper carriage 256 translates vertically along the ball screw shafts 366. An anti-runback device similar to that used in the other drives mounted between the upper end of the spline shaft 376 and the gear reducer assures that in the event

of a power failure the gripper cannot run down and will maintain its desired position.

The prime mover for the gripper actuator is a low speed stepping motor 394 which drives a spline shaft 336 which extends the length of the interior of the outer barrel, similar to the gripper drive mechanism. A sprocket 396 and chain drive 398 transfer the drive power to a flexible shaft 399 which passes to the swivel plate 312. At the swivel plate the power is transferred to a second spline shaft 370 which runs down from the swivel plate 312 to the top of the handling tube 44. Referring now to FIGS. 22 through 25, this spline 370 passes through the gripper carriage 256 where it engages a splined gear 400 which is mounted to the gripper carriage. This gear in turn engages mating teeth on a gear 402 attached to a ball nut 404 which is held axially by an attachment to the gripper carriage. As the ball nut is turned the ball screw 406 which is attached to the actuator drive rod 352 translates to open or close the gripper fingers 342 as previously described.

The gripper rotation drive mechanism includes a motor 408, spline shaft 410, chain drive 412, flexible shaft 414, and second spline shaft 371 arrangement identical to the gripper actuator drive. Referring to FIGS. 22-25, at the gripper carriage 256 the second spline shaft 371 engages a splined gear 416 which in turn engages a gear 418 on the upper end of the gripper support tube 362. The tube 362 is mounted to the carriage through a series of bearings 372 and thus is free to rotate upon actuation of the rotation drive.

Referring again to FIGS. 18 through 20, the closure valve drive mechanism includes a motor gear set 420, spline shaft 422, chain drive 424 and flexible shaft arrangement 426 identical to the gripper actuator drive. At the swivel plate 318 the flexible shaft engages a second drive shaft 428 (see FIGS. 19 and 16) which extends down to the handling tube 44 where it is connected to a ball screw 430 mounted in the upper end of the handling tube. The ball screw 430 engages a ball nut 432 which is attached through connecting rod 434 to the yoke 280 supporting the closure valve disc 278. As the ball screw 430 is rotated the yoke 280 is raised or lowered to open or close the closure valve.

Environmental Control Systems

The systems for controlling the environment in the handling machine are divided into three categories consisting of the decay heat removal systems, the handling tube sodium level system, and the handling machine internal environmental control system.

Decay Heat Removal System

The decay heat removal system includes two subsystems: the primary heat removal system and the secondary cooling system.

The primary heat removal system consists of the handling tube and the parking tube (see FIG. 16). Decay heat given off by spent subassemblies in the parking tube 268 is transferred to the sodium by conduction. Convection currents then cause the heated sodium to rise in the parking tube 268 and pass out through the flow holes 288 to the cooling chamber 436 which is the space between the parking tube 268 and the wall of the handling tube 44. The heated sodium then descends through the cooling chamber where it gives up heat to the secondary cooling system.

The secondary cooling system is a hermetically sealed system filled with NaK and is shown schemati-

cally to FIG. 26. Each of the components of this system is also shown in more detail in FIGS. 13 through 15. While there are two such cooling system, with identical components, only one circuit will be described in detail. The cooling coil 250 for removing decay heat from the liquid sodium is supported by the offset arm 332 attached to the handling tube carriage 46 (see FIG. 19). This coil extends down into the interior of the machine, passes through the upper end of the handling tube as at 438 into the tube to a predetermined depth where it makes a loop and passes upward and exits by the same route. Both the inlet and outlet legs are supported by the offset arm and directed by the arm out through the longitudinal slot 204 in the outer barrel 28 to the flexible hose cavity 206. At the upper end of the cavity the rigid tubing 250 is coupled to a length of flexible metal hose 440 which extends down into the cavity 206 (see FIG. 15) and passes back up to the point 442 where it exits from the cavity. The length of flexible hose is sufficient to permit the handling tube carriage 46 to move through its full length of travel without binding. Such an arrangement permits the cooling coil 250 to be fully immersed in the liquid sodium in the handling tube 44 at all times and thus provides full cooling from the moment a spent fuel subassembly is brought into the handling tube. The remaining components of the secondary cooling system are all mounted on the outside of the machine and include NaK pump 212, NaK-to-air heat exchangers 210, surge tanks 214 and the associated piping interconnecting these components.

Sodium Level Control System

The sodium level in the handling tube 44 must be maintained at a level 446 (see FIG. 16) above the top of the spent subassemblies at all times. In order to assure that the level is maintained within safe limits several systems are provided. The closure valve system 52 shown in FIG. 16 is the primary system for containing the sodium and has been described previously. In practice, the closure valve is closed after the handling tube is immersed in the sodium pool in the reactor core and traps sodium along with the subassembly. The gripper system 52 is then used to apply a downward sealing force to the valve disc 278 by lowering the subassembly onto it, or by pressing down with the gripper itself. A sacrificial gas system is provided to place a volume of inert gas in the annular chamber 446 which is adjacent to the closure valve sealing interface 262. With such an arrangement, if a leak were to develop in the closure valve the inert gas, and not liquid sodium, will leak out.

As a backup for the closure valve and sacrificial gas system an emergency sodium supply system is provided. This system is best shown in FIG. 13 and includes a large tank of liquid sodium 216 mounted by suitable support structure on the topmost point of the machine. This tank is connected through a pair of telescoping pipes 450, 452 and a motor operated valve 454 to the interior of the handling tube. The first pipe 450 extends from the bottom of the tank through the top of the outer barrel and partway into the cavity. The second pipe 452 (see FIGS. 18 and 19) includes a guide funnel at its upper end (not shown) and is attached to the handling tube carriage 46 and extends below the level of the sodium in the handling tube 44. The motor operated valve 454 is located in the first pipe and is actuated by sodium level sensors in the handling tube

which will actuate the valve to allow gravity flow of sodium into the handling tube 44 in an emergency situation.

A number of systems are employed to control the internal environment of the fuel handling machine. These systems are not shown in the figures and will not be described in detail, but are necessary to control temperature and gas quality in the interior of the machine. Briefly, for temperature control heaters are provided to maintain the temperature within the machine at a predetermined temperature, around 375° F during the refueling operation when spent subassemblies are not contained in the handling tube.

The atmosphere in the handling machine is an inert gas, preferably argon, containing less than 10 ppm of oxygen. During the period when the machine is operating to transfer spent subassemblies the interior is also exposed to sodium vapors and radioactive gases and thus various conventional means are employed to control the level of these contaminants.

Removal of a Spent Fuel Subassembly

Installation of the Handling Tube/Spreader Assembly

In preparation for removal of a spent fuel subassembly, the reactor is shut down and the control rod assembly or the like is removed from the core 12 to reveal the access port 14. In a typical arrangement a large cask containing the handling plug/spreader assembly 54 will be lowered onto and sealed against the top of the reactor. A crane and trolley arrangement contained within the transfer cask will then be operated to remove the control rod island and lower the handling plug/spreader assembly 54, with the shield plug 76 in place, into position in the access port. During this installation the spreader assembly 40 is in its full up position so that it clears the reactor core. The cask containing the control rod assembly is then removed and the floor valve 34 is placed in position above the handling plug 36 and suitably secured in this location. Once properly installed the floor valve 34 is opened and a second handling cask is placed over the valve opening and actuated to remove the shield plug 76 from the handling plug. Following this step the floor valve 34 is closed and the handling cask containing the shield plug is moved to a remote location.

The rotating plug system of the reactor is then actuated to locate the access port and thus the spreader over the desired core location. Once this is accomplished the spreader drive motors 138 are actuated to insert the spreader 40 into the core and isolate the desired fuel subassembly. As has been described, the spreader isolates the desired subassembly by engaging the camming surfaces or tabs 116 on the adjacent subassemblies and pushing them away to provide clearance from contact with the chosen subassembly. Of course, if the spreader tube 56 is not exactly aligned with the desired core position, the spreader or camming tube is permitted to freely float radially to seek the desired position.

Installation and Operation of the Spent Fuel Handling Machine

The next step in the refueling operation is to position the fuel handling machine 10 above the reactor access port 14 by operation of the gantry 22 and trolley 18 to which the machine is attached. Once axially aligned the entire machine is rotated by actuating the rotation

drive 194 to bring the obround handling tube 44 into alignment with the obround opening in the floor valve 34.

Referring now to the series of FIGS. 27a-27f, FIG. 27a illustrates the handling machine 10 in the position described above, i.e., it is substantially axially aligned with the reactor access port 14 and the handling tube 44 is aligned to pass through the obround access port. It should be noted that the weight of the handling machine does not bear upon the floor valve 34, but is suspended above it. Interconnection between the machine and the reactor is accomplished by lowering the movable portion of the shield skirt 32 to engage and seal to the upper surface of the floor valve 34, thereby forming a sealed passage. Switches (not shown) mounted on the shield skirt 32 indicate when the shield skirt has properly mated with the top face of the floor valve. The space between the floor valve and the isolation valve is then purged with argon and checked for leak tightness.

Referring now to FIG. 27b, with the handling machine 10 properly coupled to the floor valve 34 the isolation valve 60 and the floor valve 34 are opened to permit direct access to the interior of the reactor. The next step is to actuate the handling tube carriage drive 46 to insert the handling tube 44 to its full-in position. Shortly before reaching the full-in position, the tapered alignment nozzle 264 of the handling tube is engaged by the upper end 48 of the spreader camming tube and the handling tube is guided into axial alignment with the spent subassembly which has been isolated by the spreader assembly (see FIG. 4). During the time when the handling tube and spreader are being brought into alignment the swiveling motion previously described in considerable detail is experienced in the handling tube carriage 46 where the spherical top surface 320 of the swivel plate 318 contacts the spherical surface 328 of the swivel cage. This swiveling action, in the configuration shown in the drawings, permits the end of the handling tube 44 to accommodate a total 1-1/4" radial misalignment from the theoretical centerline.

With the handling tube 44 properly aligned, the gripper carriage 256 is actuated to raise the gripper 50 above the valve disc 278 a distance sufficient to allow room for the valve disc to swing out of the way to open the passage from the handling tube. The closure valve is then opened to permit insertion of the gripper into the reactor until the pedestal contacts the upper end of the subassembly 42. The actuator rod 352 of the gripper is then inserted to its full-in position extending the fingers 342 and locking them in the full-out position to grasp the fuel assembly. FIG. 27c illustrates the handling machine in this position.

The gripper carriage drive 256 is then actuated to move upwards and withdraw the selected subassembly 42 from the core and into the handling tube 44. The core spreader prevents adjacent subassemblies from lifting out of the core while this is occurring. The spent subassembly 42 is raised within the handling tube 44 a sufficient distance above the valve seat to permit unobstructed closing of the closure valve 52. The machine is shown in this position in FIG. 27d. Referring still to FIG. 27d, it should be noted that the level of sodium 456 within the reactor, and thus in the handling tube 44, is sufficient to completely immerse the withdrawn fuel subassembly 42. Also, it should be noted that the cooling coils 250 remain fully inserted in the handling

tube 44 while it is in its full down position and thus are able to provide full cooling capacity at all times.

The closure valve 50 is then closed and the gripper carriage 256 actuated to lower the spent subassembly 42 until it rests upon the top of the valve disc 278 to provide additional sealing force on the valve. Closing of the valve traps the sodium in the handling tube at the desired level above the top of the subassembly. The sacrificial inert gas is then introduced into the annular space in the closure valve as described previously.

The handling tube carriage 46 is next actuated to retract the handling tube 44 above the sodium level 456 in the reactor, and it is held in this position (see FIG. 27e) for several minutes to check for gross sodium leaks through the closure valve 50. The cooling systems are also checked for proper operation at this time.

Once it is determined that the closure valve 50 and cooling systems are operating properly the floor valve 34 and the isolation valve 60 are closed.

The space between these two valves is then purged with argon and checked for leaks. The shield skirt 32 is then raised to uncouple from the floor valve 34 and the crane 22 and trolley 18 are used to transport the handling machine 10 to the decay tank. At the decay tank, similar steps are taken to insert the handling tube 44 into the tank and to deposit the spent subassembly therein.

In an actual refueling operation, a second handling machine similar to the spent fuel handling machine just described brings a new fuel subassembly to the reactor access port and inserts it into the reactor core. The spreader assembly remains in the core during this operation to isolate the core position into which the new assembly is being inserted.

Removal of the handling plug/spreader assembly and installation of the control rod guide assemblies is accomplished by reversing the steps followed in installing these assemblies onto the reactor.

While this preferred embodiment of the invention has been shown and described, it will be understood that it is merely illustrative and that changes may be made without departing from the scope of the invention as claimed.

What is claimed is:

1. In combination, a liquid metal cooled nuclear reactor and a fuel handling machine for the reactor, said reactor including: a vessel containing liquid metal coolant; a core surrounded by said coolant, said core containing a plurality of fuel subassemblies, the level of coolant above said subassemblies being at least equal to the length of the subassemblies; a closure head for said vessel having an entrance port therein; said fuel handling machine comprising: control and drive assembly means positionable above and spaced from said entrance port; a tubular barrel extending down from said control and drive assembly means; a seal valve attached to the bottom of said barrel for making sealed communication with said entrance port, said communication extending into said barrel; a handling tube mounted within said barrel for passing through said entrance port into said reactor and defining an annular space between said tube and said barrel; a closure valve in the bottom of said handling tube through which a fuel subassembly may be passed; means for opening and closing said closure valve; means extending from said control and drive assembly means for lowering said handling tube into said vessel to a position adjacent to the upper end of said fuel subassemblies and for re-

tracting said handling tube back into said tubular barrel; gripper means vertically movable within said handling tube for being lowered and extended down through said open closure valve for engaging a selected fuel subassembly; means extending from within said control and drive assembly means, through said handling tube, for raising and lowering said gripper means; heat transfer means for continuously removing heat from liquid metal trapped within said handling tube; whereby upon engaging said seal valve with said entrance port, lowering said handling tube into said reactor, opening said closure valve, lowering said gripper means to a position adjacent a subassembly, engaging said subassembly with said gripper means, raising said gripper means to draw said subassembly into said handling tube, closing said closure valve, and raising said handling tube into said barrel, said fuel subassembly is contained in said handling tube immersed in liquid metal coolant which has been captured in said tube and is cooled by said heat transfer means.

2. The combination of claim 1 wherein said heat transfer means comprises: a cooling coil carried by and extending into said handling tube and having an inlet fitting and outlet fitting at its upper end, said tubular barrel having a vertically extending longitudinal slot therethrough, through which said inlet and outlet extend; a hose cavity communicating with said slot substantially along the full length thereof; flexible coolant hoses, one each, in flow communication with each of said inlet and outlet fittings; a heat exchanger mounted on the exterior of said tubular barrel and connected in series with said cooling coil; means for circulating heat exchange fluid from said heat exchanger to said cooling coil for the transfer of heat from said handling tube to the atmosphere exterior of said valve.

3. The combination of claim 1 wherein said means for lowering and retracting said handling tube comprises: a plurality of ball screws extending down from within said control and drive assembly means through said annular space and supported at the lower end of said barrel; a handling tube carriage including a cage assembly slideably disposed within said tubular barrel and having a circumferentially extending interior cage defined by a flat lower surface and spherical upper surface, said cage assembly further including a plurality of ball nuts attached thereto which operatively engage said plurality of ball screws; a swivel plate having a spherical upper edge and flat lower surface disposed within said cage, said plate being sized so as to permit limited swiveling movement thereof within said cage; means for rigidly attaching said handling tube to said swivel plate and for maintaining said handling tube and said plate in spaced vertical relation with one another; spring means disposed between the lower surface of said swivel plate and the flat surface of said cage, sized to lift said plate from said cage lower surface to permit swiveling movement of said plate to occur; means within said control and drive assembly means for rotatably driving said ball screws to cause said handling tube carriage and handling tube to move vertically within said barrel.

4. The combination of claim 1 including: a tank containing liquid metal coolant mounted above the upper end of said tubular barrel; means for effecting fluid communication between said tank and the interior of said handling tube in response to a drop in the level of coolant in said handling tube to replenish the coolant therein through gravity flow of coolant therebetween.

5. The combination of claim 2 wherein said handling tube comprises an outer obround casing and an inner cylindrical tube having a diameter larger than a fuel subassembly, said inner tube being eccentrically supported within said obround casing to define a chamber therebetween, said inner tube further being in axial alignment with said gripper means and including through openings providing flow communication between said inner tube and said chamber, said cooling

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coil extending downward into said chamber, whereby when a spent fuel subassembly is contained in said handling tube, it is within said inner tube and heat given off by said subassembly is transferred to the sodium in the inner tube by conduction, convection currents cause the heated sodium to rise in said inner tube and pass out through said through openings to said chamber where heat is given up to said cooling coil.

* * * * *